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The Series System of Street Lighting Distribution

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The series system of distribution has been used almost universally for street lighting since the first use of electric lamps.

Lamps, both arc and incandescent are very simple and more efficient when designed for series operation than are the multiple type. The maintenance of constant power at the lamp terminals where lamps are thinly scattered over a wide area is much easier with a series system of distribution than with any other system. The burning of all street lamps in the city for certain specified hours makes it desirable to turn the whole circuit on and off from a certain point so that such a system whether series or multiple cannot be used to distribute power for other purposes. As therefore, a special system is necessary for the street lamps, it has usually been made of the series type for the above reasons.

The special apparatus required to operate a series system from constant potential is very simple and inexpensive. The constant-current moving-coil transformer is the main factor in the maintenance of the necessary constant current. The film cut-out socket for the lamp enables the continuity of the circuit to be maintained when the incandescent lamp breaks or is removed. Both are very simple and reliable even with unskilled operators.

Any system of street lighting of sufficient merit to supersede the series system must depend primarily on the development of simple, reliable and inexpensive control apparatus for the individual lamps to enable them to be operated on the existing multiple distribution circuits.

A SERIES system of lighting distribution is one in which all the current in the circuit passes through each individual lamp in turn. The power as measured in watts taken by each individual lamp is determined by the resistance drop across that lamp, the current in all the lamps being the same. By properly regulating this current at the station, the wattage and illumination is maintained at a constant value, regardless of the pressure drop in the conducting wires of the system. Special short circuiting devices are employed to maintain the continuity of the circuit when the lamps burn out and to maintain a constant current in the circuit with the various conditions of load.

Such series systems are employed on a large scale to operate various types of lamps for street lighting. Conspicuous examples are the Mazda lamps in Chicago, the flame carbon arc lamps in Chicago and Indianapolis, the metallic flame or luminous arc lamps in Detroit, Pittsburgh and St. Louis as well as the old carbon arc lamps, both open and enclosed, which these lamps replaced. Where a suitable current and frequency are used the same circuit may operate both arc and incandescent lamps without difficulty.

As distinguished from the series system the multiple system of distribution requires lamps of the same voltage as the circuit rating, each of which has a resistance permitting the desired current to be taken. A simple switch at each lamp disconnects it individually from the circuit. As practically all factory and residence lighting is so operated approximately 95 per cent of the incandescent lamps used in this country are on multiple systems.

Other systems combine the principles of the series system with that of the multiple system by connecting a number of lamps in series and operating this series of lamps on a multiple circuit of higher voltage than is suitable for single lamps. Street cars thus use five of the substantial 110 volt lamps in series on their 550-volt circuits. However when one lamp breaks a filament, the other four will not operate as the circuit is then open. In some street lighting systems, notably at Milwaukee, series street lamps are connected in series and operated on constant potential in a similar manner. In such cases alternating current is employed

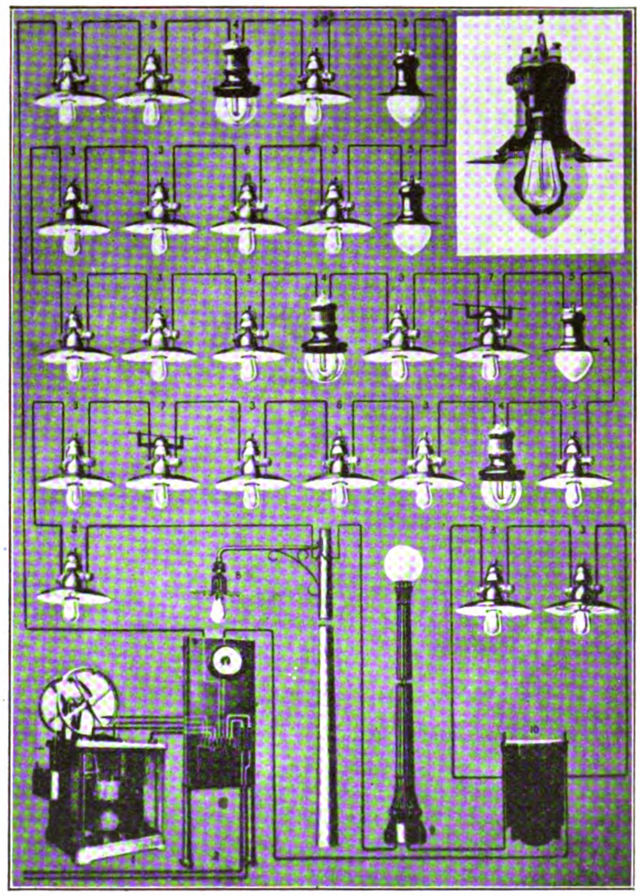

FIG. 1—STREET LIGHTING APPARATUS AS CONNECTED TO A CONSTANT CURRENT MOVING COIL REGULATOR

and special devices are provided to maintain the continuity of the circuit when individual lamps go out.

EXTENT OF USE

Approximately 1,000,000, street lamps in the United States are supplied by series distribution circuits. This constitutes practically the entire street

To be presented at the 357th meeting of the A. I. E. E., Chicago, Ill., January 9, 1919.

lighting distribution system of a large majority of the operating companies. Although requiring but a small proportion of the total kv-a. generating capacity, the system is of great importance to operating companies, because of the conspicuous position and essential duty of each small unit. It is especially notable that in its street lighting work, many operating companies render service to every one of the inhabitants whereas only 20 per cent or less, of the people may be making use of electricity in their homes. Yet, its total actual cost may be only 1 or 2 per cent of the total city budget and seldom over one dollar ($1.00) per year, per inhabitant.

Development

Although a great many other systems involving substitutes for the constant-current generator or moving-coil regulator have been tried out on a limited scale since the first introduction of the electric lamp some forty years ago, the series system is of as great relative importance as ever in street lighting, and is changed only slightly from the original concept brought out with the development of the first arc lamp by Mr. Charles F. Brush. This is an indication of the simplicity and fundamental soundness of the scheme.

The change from direct current to alternating current involved practically no change other than the lamps themselves, and the station equipment. The lines were seldom involved.

Advantage of a Series System

Street lamps constitute a comparatively small load in kv-a. which must be operated at various spacings over a wide area. The line cost per kv-a. of installation is relatively high. This is offset to a certain extent by a load factor of approximately 45 per cent where a 4000-hr. per year schedule is maintained. Furthermore, special precautions must be taken to maintain constant power at the lamps, regardless of the wide distribution. The series system is particularly adaptable to this service.

Consider that power is supplied to a 500-watt lamp every 500 feet along a street. A conductor smaller than No. 8 gage, is seldom used, as it would be too weak to be dependable, from a mechanical standpoint. From current-carrying consideration, a No. 14 wire would be ample although the watts lost in transmission, would be approximately four times as high as in a typical street lighting system.

If 110-volt multiple distribution is attempted, even with No. 8 conductor, not over two such lamps, the most distant being 1000 feet away, can be successfully operated, because of the poor regulation resulting from the voltage drop in the conductor. On a similar series circuit, 100 or more of such lamps, or a much larger number of smaller lamps, with as much as 40 miles of line wire, are readily operated.

Under such conditions there would not be over 50 kw. in load per square mile of territory served, and where the lamps are small, or spaced even further apart due to the presence of gas lamps in many locations or due to a scattered population, this load may be of the order of 5 kw. per square mile and 1 kw. per mile of single wire.

The low current in the series circuit prevents excessive drop in the line even with No. 8 conductor. The regulator compensates perfectly for this drop. The voltage of a single circuit is thus the sum of the voltages of the lamps on this circuit, and the line drop. It is evident that the long high-voltage circuits have the great advantage of less apparatus per kilowatt of load because fewer circuits will be required. Also a lower percentage of the line is used in simply running back to the station for purposes of control.

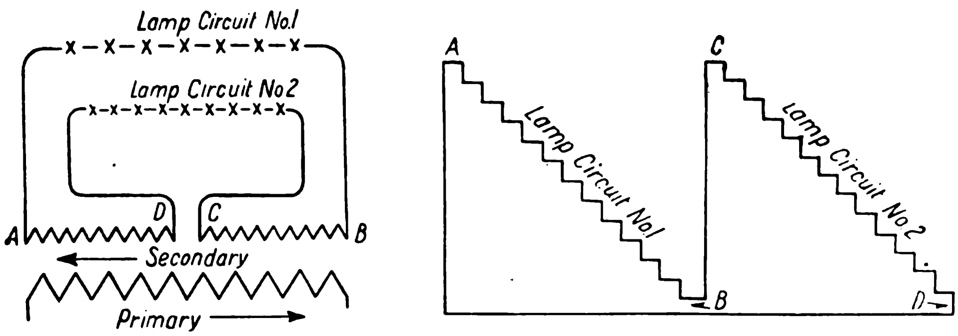

Fig. 2—Regulator with Two Interconnected Secondary Circuits and Development of the Diagram Showing the Voltage to Ground in the Various Parts of the Circuit.

The size of such a circuit may be limited by any one of several factors.

1. Voltage of the circuit to ground.
2. Number of lamps to operate on one circuit.
3. Insulation of lines and equipment.

Series lighting circuits on poles are subject to many grounds due to trees, lines breaking, crosses with other circuits and other causes. If an excessive voltage is supplied to any circuit an accidental ground at any point on the circuit causes a heavy strain on the insulation at other points because the drop across the large number of lamps is so great. This drop can be greatly reduced by cutting the circuit in parts and connecting a portion only of the generator or regulator winding between these sections. The whole combination con-

sisting of from two to four sections is thus connected in series as shown in Fig. 2 and takes the same current throughout the circuits. Such a system has been used in the d-c. arc generators for many years and also in the constant-current regulating transformers.

Grounds must be promptly removed from such a system. Where double grounds occur, one on each of two circuits, they may, if of low resistance, both be placed near enough the station (Fig. 2 at *B* and *C*) to practically short circuit one section of the regulator winding and the adjacent lamps, thus causing the current in that part of the circuit to increase to nearly 100 per cent of normal, while the remaining lamps would get practically no current. This double ground rarely occurs with good line construction, maintenance and methodical testing of the circuits. Equality of current in the two circuits may be insured by a relay so connected as to disconnect the regulator or circuits if current in the two circuits becomes unbalanced. In

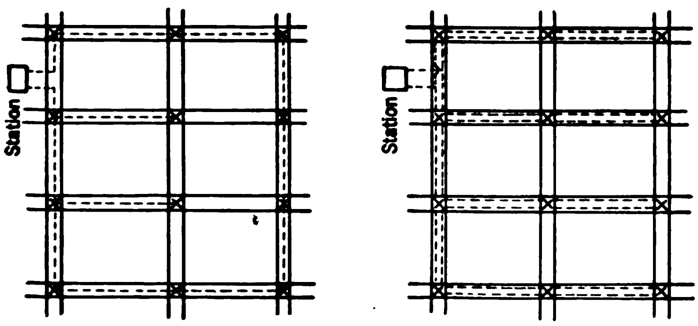

Fig. 3—Diagram of a Series Circuit on Streets Showing the Saving of Wire that May be Made by Using a Single Wire Circuit

general the merits of such a system of interconnection are so great that it is in very general use, particularly where the voltage of a circuit would otherwise exceed 5000.

In many cases one circuit is used for the all night lamps of a white way system and the others for the half night lamps. The high light load efficiency of the regulating transformer makes this arrangement very suitable.

The number of lamps on a circuit is influenced largely by the density of the lighting units and their size. In extreme cases 500 are found on a single circuit where there is a wide area of suburban territory to be lighted only by low candle power lamps. The numerous lamp loops of such circuits greatly increase the chances of open circuiting the whole system. To reduce the consequences of this the wiring should be arranged in loops so that cut-outs can be installed which automatically short circuit and disconnect a broken loop (Fig. 3 shows typical loops).

The cost of insulating lines and equipment rises rapidly with the higher voltages. This fact must be considered and balanced with the cost of additional circuits necessary to maintain low voltages. On overhead lines some systems successfully operate arc lamps up to 8000 volts. Underground circuits are seldom operated at more than 5000 volts as any breakdown in their insulation is much more serious from the standpoint of repair.

It is of great advantage to be able, in a series circuit, to operate the lamps on one street from one wire of the circuit alone without it being necessary to have the return circuit on the same street (Fig. 3). This may save as much as 50 per cent of the total wire required, and as many street lighting circuits are on pole lines already necessary for residence lighting such a use of a single wire system means the saving of a very considerable portion of the total expense. Little or no additional wiring in such single wire circuits is necessary to create loops by which large sections can be isolated either automatically as previously described or by means of a jumper. The automatic current regulation of the constant-current moving-coil transformer makes this perfectly feasible even though 90 per cent or more of the lamps be so cut out of circuit.

Line reactance with such small currents involved may usually be ignored as its only effect is to slightly reduce the load carrying capacity of the regulator. Variations of the lamps themselves from their rated voltage have a much greater effect on the total regulator capacity. For overhead lines this reactance drop at 60 cycles in single wire circuits is approximately 50 per cent and in return wire circuits, 25 per cent respectively of the resistance drop.[1]

Control

The operation of the street lighting lamps from dark until dawn or over some other fixed period makes a special condition of control not required for any other type of service. It is of great advantage from the standpoint of time and labor to be able to control all these lamps from a single point. Such has generally been the practice, thus making it impracticable to use the street lighting circuits and lines for any other service. Therefore, where a separate circuit is run for street lighting the series system has many advantages from the standpoint of installation costs and regulation over any other system.

Lamp Characteristics

In general it has been well worth while to make special lamps for series operation on account of the higher electrical efficiency or lumens per watt input.

In direct-current series arc lamps the wasteful sustaining resistance necessary to the multiple arc is omitted and the constant-current regulating device itself sustains the arc without material loss of power. In consequence of this difference, the direct-current arc lamp electrical efficiency is approximately 70 per cent

1. Formulas in Pender's handbook or in Bureau of Standards, Vol. 4, No. 2, page 317.

for the multiple and 95 per cent for the series lamp. Similar figures for an alternating-current system of enclosed carbon arc lamps so widely used at one time, were 90 per cent and 95 per cent respectively. The smaller apparent difference is, of course, due to the use of a reactance coil, instead of a resistance in the multiple arc lamp for sustaining effect.

The series system has been retained for use with Mazda lamps, as the efficiency of these lamps when made for a series system is much better than that of multiple lamps, being, in the case of the 100-c.p., 6.6-amperes series lamp, some 20 per cent higher than a 110-volt lamp of such a candle power.

Direct-current arc lamps were used on the early series circuits because of the greater steadiness and efficiency of the arc on direct current than on alternating

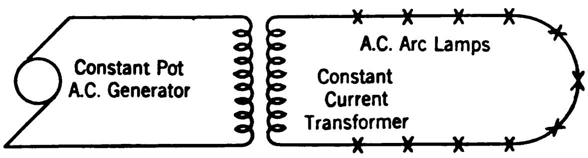

FIG. 4—CONNECTIONS OF A SERIES CIRCUIT TO A CONSTANT POTENTIAL SOURCE BY MEANS OF A CONSTANT-CURRENT TRANSFORMER

current. The alternating-current enclosed arc although much less efficient became very popular when alternating-current systems of generation and distribution became common because a series alternating-current circuit could be derived, from the usual 2300-volt constant-potential bus by a simple constant-current regulating transformer. This transformer had only a fraction of the first cost, maintainence cost or floor space of the motor generator or rectifier set necessary to operate a direct-current series circuit from the alternating-current constant potential bus. Yet the improvement, from the illumination standpoint, over all predecessors of the metallic flame, or luminous arc lamp introduced about 1907, was such that many of the direct-current series circuits necessary for their operation have since been installed.

Where incandescent lamps only are used there is obviously no need for direct current and it is well worth the slight expense to change the regulating equipment from direct to alternating current when direct-current series arc lamps are replaced by incandescent lamps. Such a change usually only involves the replacement of the station apparatus by a constant-current regulating transformer. An alternating-current circuit enables the use of the 20-ampere lamps from auto-transformers where high candle power lamps are desired. Safety coils can also be used on alternating current enabling the use of series lamps on fire alarm brackets, traffic posts and bridges in a way practically impossible on a high-voltage direct-current circuit with any degree of safety.

Frequency has had but slight effect in the development or use of series circuits. Apparatus has been available for all commercial frequencies except that arc lamps were never satisfactory on 25-cycle circuits.

APPARATUS

In the simplest and most commonly used series systems, a special constant direct-current generator or a moving-coil transformer for alternating current is required at the station to control the circuit and to maintain the correct current at the lamp.

In the old direct-current arc lighting machine, special designs utilized the reactance of the armature to prevent excess current in the lamp circuits, and used devices for shifting the brushes to obtain the necessary voltage up to the limits of the machine. Some of these regulators were extremely accurate and were sensitive enough to operate the high efficiency incandescent lamps now commonly used. The constant-current regulator commonly used for alternating current depends upon the electrical repulsion existing between the primary and secondary coils of a transformer under load to produce and maintain a constant current in the secondary or lamp circuit. Such a regulator is of great value because it can automatically maintain a fixed secondary current through any number of lamps from one up to its maximum capacity or with a wide fluctuation of the voltage on its supply circuit. When it is realized that an increase of 3 per cent in the current of the lamp circuit cuts the life of an incandescent lamp in half and

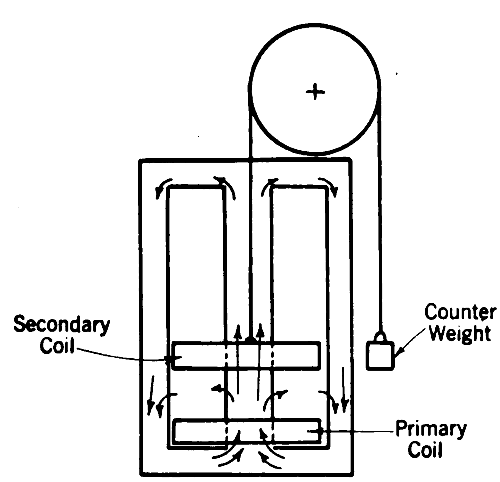

FIG. 5—FLUX RELATIONS IN A MOVING-COIL REGULATING TRANSFORMER SHOWING THE LEAKAGE OF FLUX BETWEEN THE STATIONARY AND THE COUNTERBALANCED MOVING-COIL

thus doubles the renewal cost, it can readily be appreciated that such a regulator is very cheap protection for the lamps as compared with any system that does not compensate automatically for all variations. To get a more definite idea of this relation it should be remembered that in extreme cases such as certain suburban districts using a great number of low candle power lamps the value of the lamps on the circuit is equal to that of the regulator controlling them. Under normal

conditions these lamps are renewed about three times per year. Accurate and reliable regulation is therefore necessary to keep these lamps up to rated candle power without getting at times a current sufficient to cause premature burnouts and increased expense in lamp renewals as well as in deductions for lamp outage. Renewals of four times per year would in this case require excess lamps equal the value of the regulator. The moving coil regulator is the only device which automatically compensates accurately for short circuits and double grounds on the series line or for voltage variation of the constant potential supply.

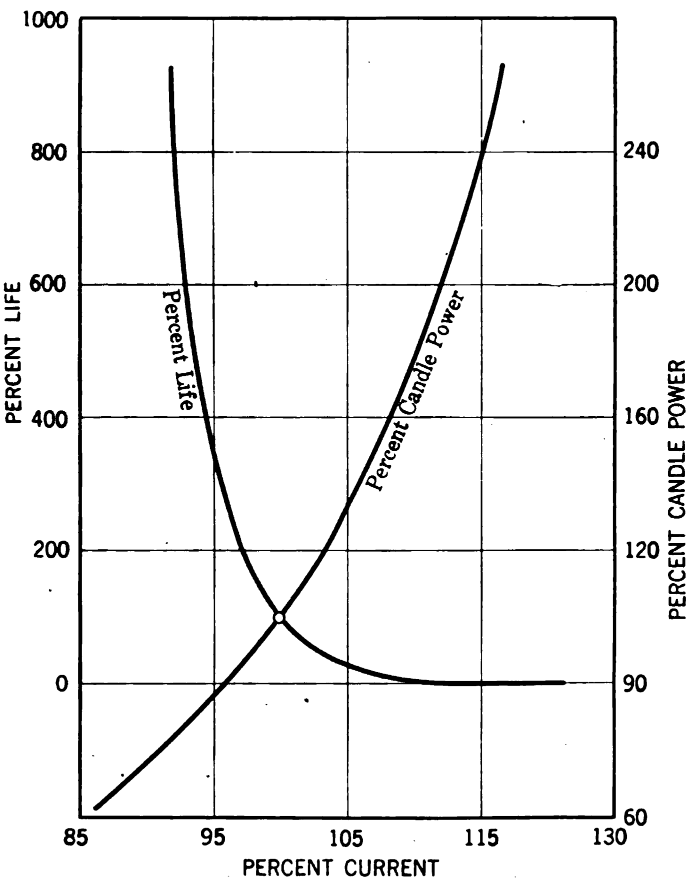

Fig. 6—Curves Showing the Change in Candle Power and in Lamp Life with a Change of Current in a Tungsten Filament

Such regulators are so substantial and reliable that small sizes have been successfully mounted on poles in transformer cases and operated by a time switch. Wherever possible however, they should be installed in a station so that the line can get more frequent and careful testing and an ammeter can be continuously kept in the lamp circuit.

In every series circuit the devices used on it must have a means of by-passing the current when the device itself is inoperative to prevent the opening of the whole circuit.

The arc lamp has a mechanism arranged as in Fig. 7 so that a shunt coil connected across the arc causes a switch to be closed and the arc short circuited when the drop across it becomes excessive. Another coil in series with the arc and line acts to give the correct spacing of the carbons or electrodes.

For the incandescent lamp a simple form of switch is incorporated in the socket. An insulating film is placed between the two sides of this switch. This film has

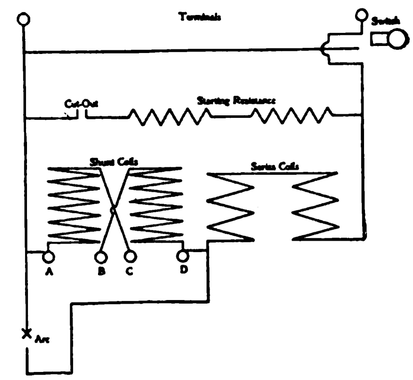

Fig. 7—Schematic Diagram of Circuits in a Series Arc Lamp Showing Three Parallel Circuits:

(1) Main circuit through the series coil and the arc.

(2) Shunt circuit to pull the carbons together when the voltage across the arc increases.

(3) Starting circuit consisting of resistance in series with a switch to cut it out when the arc burns.

The drop across the starting resistance through which the current first flows causes current to flow through the arc and series coil This coil pulls the carbons apart opening the starting circuit. The shunt coil prevents the arc voltage becoming excessive and can close the switch, if necessary, in the starting circuit thus maintaining a safe current path through the lamp.

normally only to withstand the drop across the lamp filament, *A* (Fig. 8) of 10 volts. However, if the lamp burns out the filament itself gives the effect of an infinite resistance, and the full generated voltage of the regulator or generator is impressed upon the insulating film, causing it to puncture and short circuit the lamp filament. In a moving coil regulator this

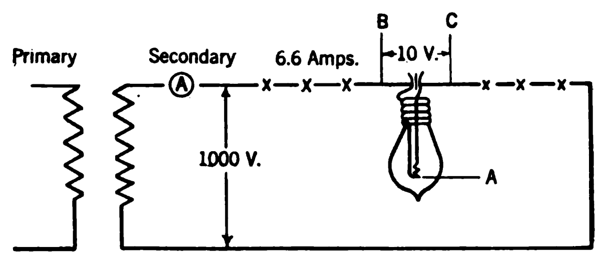

Fig. 8—The Film Cut Out Socket for Incandescent Lamps

When lamp filament *A* breaks, the voltage *BC* rises from that of the lamp to that of an open circuited regulator causing the film to break down and short circuit the lamp.

maximum voltage is approximately 25 per cent more than the full load voltage. A switch in the socket operated by the insertion of the lamp in this socket short-circuits this film when the lamp is removed.

Such film cutout sockets are very simple and inexpensive, and enable men with little training easily to renew the lamps, even under trying conditions of lamp location and bad weather.

In general, devices other than lamps have seldom been used to any great extent on street series circuits. On account of the dark until daylight schedule it is often

desirable to operate lamps indoors and around places where the high voltage possible on a series circuit cannot be tolerated. Underground circuits are often included in this status on account of the great expense of high-voltage cable. In such cases a special series transformer or safety coil is used. This safety coil can supply a small wattage at constant current and low voltage on the secondary circuit and yet be insulated for an extremely high voltage on the main series circuit.

Instruments or meters of a special nature are seldom required for series circuits. A high grade ammeter should be in series with the lamps for upon it depends the accuracy of the adjustment of the regulator and the life and candle power of all the lamps. The possible accuracy and permanence of the adjustment of the moving-coil regulator is well comparable to that of the ammeter, and little difficulty is experienced in its operation. Municipalities sometimes require a chart of the current in the series circuit and maintain curve drawing ammeters for this purpose. In other cities a jack on a pole allowing the insertion in the circuit of a plug with ammeter fulfills all requirements.

Maintenance

Maintenance and testing of series circuits is special only in that checks through the day are advisable in order to repair before dark any damage that may have occurred during the hours of non use. Troubles usually show in the form of grounds and open circuits. Simple electrical tests locate troubles, of this nature. They must be promptly removed to avoid damage to the lamps or interruption of service during the dark hours.

Summary

The advantage of the series systems of street lighting distribution consist of (1) effectiveness; (2) simplicity of control; and (3) high electrical efficiency of lines and lamps.

The disadvantages are (1) high cost of line per dollar of income; (2) high voltage; (3) special lamps.

The ideal system ultimately should be one to operate a highly efficient standard lamp from the existing multiple distribution lines necessary for residences and factories. Complicated special apparatus and special wiring, other than to the lamps is thereby eliminated. Reliable and inexpensive control devices must be available to turn the lamps on and off. Although much time and expense have been spent on such development ever since the lighting industry started, none has ever been sufficiently perfected to be worthy of generally replacing the simple series system.

TECHNICAL REPORTS ON INDUCTIVE INTERFERENCE

The Joint Committee on Inductive Interference, whose report to the Railroad Commission of the State of California was published in the A. I. E. E. Transactions for 1914, conducted a very exhaustive investigation of the phenomena of inductive interference between electric power and communication lines. In the course of its investigations the Committee compiled a number of technical reports on different phases of the subject, and owing to a wide demand, the Commission has published the most important of these reports in book form thus making them available for general distribution.

This volume, entitled "Inductive Interference" is bound in morocco leather and includes 1060 pages. It consists of the 30 most important technical reports of the Joint Committee selected from the seventy-one which were issued from time to time during the investigation. It also includes the preliminary and final reports of the Committee to the Commission, and the General Order No. 52 of the Commission prescribing rules and principles governing the construction and operation of power and communication lines for prevention and mitigation of inductive interference.

The book represents the results of extensive field and laboratory tests and investigations carried on for a period of over five years by a staff of electrical engineers from all parts of the United States, at an expense in excess of $100,000, and represents the thought and study of some of the most prominent power and communication engineers of the country.

There is no doubt that this volume covers the subject of inductive interference between electric power and communication circuits in a very broad and comprehensive manner and is, without question, the most complete and authentic work of its kind in existence. It will become an indispensable textbook for all students of the subject.

Subscriptions for this book have been received from interested engineers in most countries of the civilized world. A limited number of volumes have been printed in addition to the original subscriptions and are being distributed by the California Railroad Commission, San Francisco, at the low price of $10.00 per volume.

It is advisable for such engineers and others that want to secure this book to place their orders with the Commission as early as possible.

The United States Government has entered into contract with French Republic, under terms of which French Government is permitted to purchase $25,000,000 worth of machine tools from surplus stocks of such tools held by War Department in United States. French Government is to pay for such machine tools as it may purchase in ten-year 5% bonds of French Republic, payable in gold coin of United States.

Multiple Systems of Distribution for Street Lighting

BY WARD HARRISON

Engineering Department, National Lamp Works

The wider use of multiple lamps supplied from standard secondary distribution systems is considered as a step in simplifying operating problems and reducing the disproportionate cost which goes to cover fixed charges on special equipment and additional lines for street lighting only. The advantages in simplicity and flexibility of multiple connected lamps are discussed with particular reference to the frequent changes and extensions of street lighting service required in growing cities. The more general adoption of multiple street lighting is stated to be contingent upon fuller standardization of suitable methods of control applicable generally to existing electrical power distribution systems. Different devices in use or proposed for control of multiple street lamps are briefly described and the characteristics desirable in such apparatus are outlined. Attention is directed to the small differences in efficiency of present multiple and series incandescent lamps.

THE problem of securing street lighting most economically from multiple connections is one whose possibilities are far from exhausted, for multiple street lighting circuits and suitable control devices have not as yet progressed to the same degree of standardization as those of the series type. In the past, each individual case has been worked out, as far as possible, by adapting existing apparatus to meet the requirements of the particular situation. The purpose of the present paper is to review the systems now in use with their methods of control, and to indicate some of the more promising avenues of development.

FIG. 1—TYPICAL OVERHEAD SERIES ARC LAMP POST SHOWING INSULATING HANGER

EXTENT OF USE

In European cities, multiple street lighting systems are practically as common for both arc and incandescent lamps as are series systems in this country. Even here, where series circuits predominate, there are, notwithstanding, a large number of straight multiple systems in operation. It is true that they are largely confined to cities where low tension current only can be used. Of these cities, New York, with many thousands of such lamps, is the most prominent example. It is worthy of note, however, that in cities nominally lighted from series circuits, considerable numbers of street lamps will be found operated from the multiple distribution system.

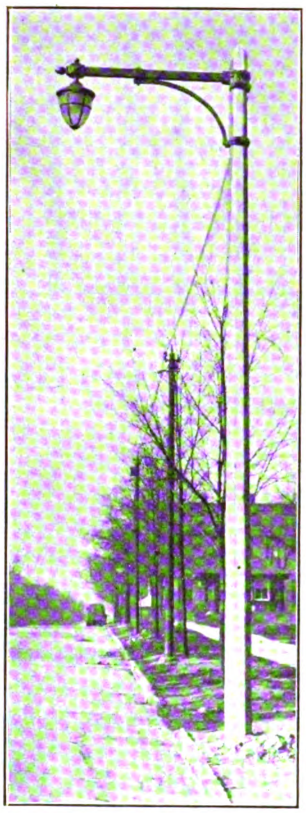

FIG. 2—SIMPLIFIED TYPE OF FIXTURE DESIGNED FOR MULTIPLE INCANDESCENT STREET LAMPS

ADVANTAGES

The following advantages which contributed to the standardization of multiple distribution for all other types of electric service apply also to street lighting.

1. Widest choice in number and sizes of lamps to be connected to circuit.

To be presented at the 357th meeting of the A. I. E. E., Chicago, Ill., January 9, 1919.

2. Ease of adding more lamps or lamps of higher wattage.
3. Simplicity and low cost of fixtures and accessories.
4. Safety.

The matter of flexibility is of immediate importance in the problem of designing street lighting for American cities and towns. There is not only steady growth in population and area covered, but there are also unexpected demands from time to time for increased street lighting service in given areas. The result, with series circuits of units of 50 to 100 lamps included on a single line, is that there must be an almost continual process of rearrangement and redivision of lamps among different circuits. In many cases service can only be provided after considerable delay and at relatively high cost, because existing circuits are so completely loaded that the addition of a few lamps makes necessary an extended revision of the system. No such limitations attend when the street lamps are operated from the general multiple distribution system.

An additional advantage of multiple street lighting is that, as mentioned above, the multiple circuit is now used exclusively by central stations for every other service. Were it used generally in street lighting as well, the reduction in types of apparatus required and the resulting simplicity of operation would benefit both the electrical manufacturer and the central station. At the present time, when a new real estate sub-division or allotment is opened, it is common practise for the lighting company to run a set of 2300-volt feeders to cover the plot, and to furnish service to houses as they are built. At the same time, a series transmission line is extended to furnish the necessary street lighting for the sub-division, and, in anticipation of increased requirements for service, both supply circuits are installed with a large excess capacity. The principal reasons for this duplication of service have been:

1. The arc lamp is inherently a constant current device and gives its best operation and greatest efficiency on series rather than on multiple circuits.
2. The series circuit is the simplest and most efficient method of supplying energy to comparatively small units scattered over wide areas; in many cases electric street lighting ante-dated the general use of electricity in residences by a considerable period.
3. A separate system of distribution has furnished a convenient means of automatically lighting and extinguishing street lamps from the central station.

There is an insistent demand for the extension of electric street lighting service in territory not now served by series lines, as for example, in Ohio cities, where in the past a considerable portion of the lighting has been furnished by natural gas, the supply of which is being rapidly depleted. In such territory the residences are, for the most part, furnished with current from overhead circuits along the rear lot lines, and the introduction of a pole along the street, to carry the series circuit has often met with a decided protest from the property holders. On the other hand, the cost of underground construction, with ducts running parallel to the curb, is almost prohibitive, especially in view of the increasing frequency with which concrete driveways now cross the parking in residence districts. High-tension underground lines passing through private property from the rear lot lines to the street, also involves expensive construction if safety is to be assured. Taken altogether, the conditions point toward the use of low tension multiple circuits from the pole lines in the rear to the posts on the street, brought out either overhead or underground, as occasion may require. Under these circumstances the underground construction may be in the form of a relatively inexpensive lightly-insulated sheathed conductor protected simply by fuses at the transformer. Such a conductor is very

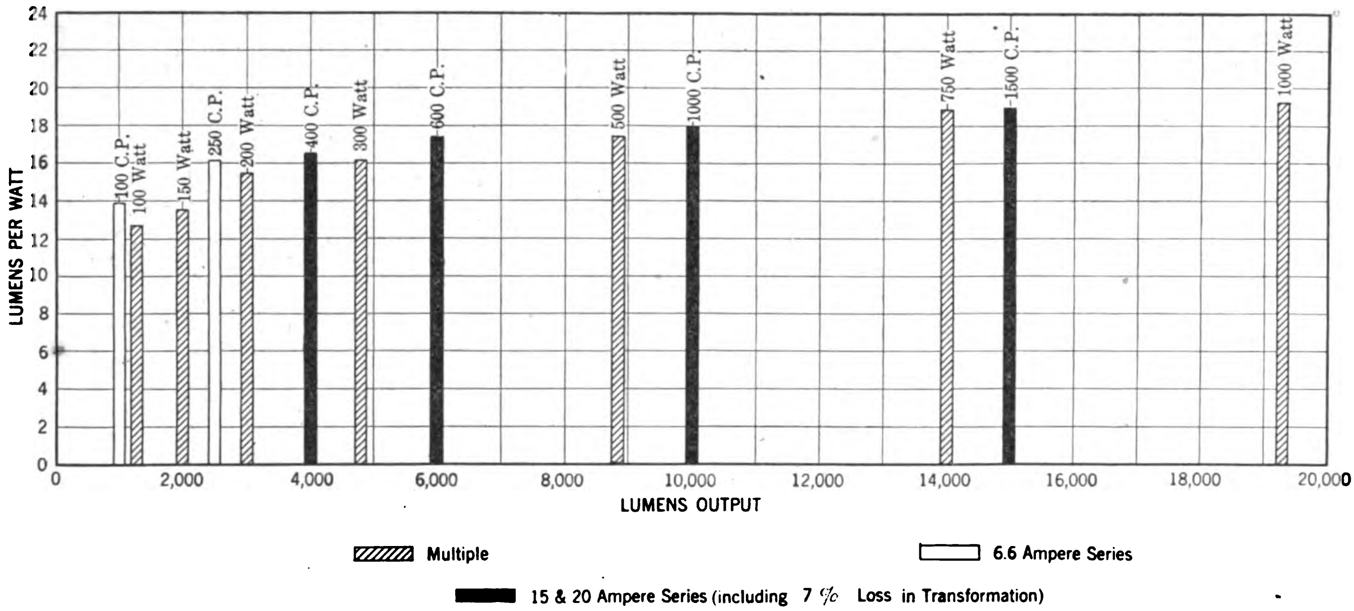

FIG. 3—COMPARATIVE EFFICIENCY OF SERIES AND MULTIPLE INCANDESCENT LAMPS

much less expensive than that designed for high tension work, and it can be installed without opening a wide trench across the lawn. If such a conductor is accidentally severed no serious harm can result, and the loss in itself is small.

Control

Today if incandescent street lamps were to be operated throughout the twenty-four hours instead of at night only, there would be no discussion as to the desirability of connecting them to the existing multiple distribution system, but the obvious difficulty in this practise lies in obtaining a thoroughly satisfactory method for turning the lamps on and off. Of course, wherever the load is sufficiently concentrated to justify a separate circuit from the substation, as in the case of many so-called White Way installations in the business streets of cities, the lamps may be switched at the substation in the same way as in the case of series circuits. Ususally, however, to bring the circuits back to the sub-station entails a prohibitive expense in copper and it is necessary to supply the lamps from several different transformers or feeders located nearer the lamps. For example, in the case of residence districts, it would be particularly desirable if the street lamps could be supplied from the same circuits located in each block, which now provide service for the residential consumers, as in Fig. 8.

The simplest plan is of course to have the lamps turned on and off by hand through the agency of a patrol messenger. Where labor is cheap, as in some of the European and Asiatic countries, this has been found a satisfactory and economical solution. In this country there are many cities where the White Way lighting is turned on and off by the policemen on duty. However, in view of the higher cost of labor in the United States and the extended distances between lamps, hand control is less desirable. Furthermore, the fact that gas companies are forced to rely upon manual control, and the difficulties which they have experienced, have served to deter electric lighting companies from resorting to it, excepting where there was no practical alternative in the way of a mechanical or electrical control.

Most of the efforts toward the development of remote control of multiple street lamps on 110-220-volt circuits can be grouped under three general types of systems,—cascading, relay switches operated from a pilot wire, and automatic clock or impulse-operated relay switches without separate control circuit. Diagrams illustrating these three methods of remote control are shown in Figs. 4, 5 and 6.

In the cascade method the section of lamps nearest the sub-station or control point are switched on and off by hand or a clock control switch. Energizing of this section serves to close a relay operating the switch for a second section. At the end of the second section is a similar relay which, being energized, closes the circuit for the third section of lamps, and so on. Opening the switch on the first section of lamps serves to de-energize the other sections of lamps in the same order. It is obvious that a method of this kind can be used for either alternating- or direct-current systems, or even a combination, and the load may be carried from as many separate transformers or sets of feeders as desired.

In the cascade system a failure of current supply in any section will turn out the lamps in succeeding sections of that cascade. However, this difficulty can be minimized by provision for hand operation of the switches in case of failure of one of the units.

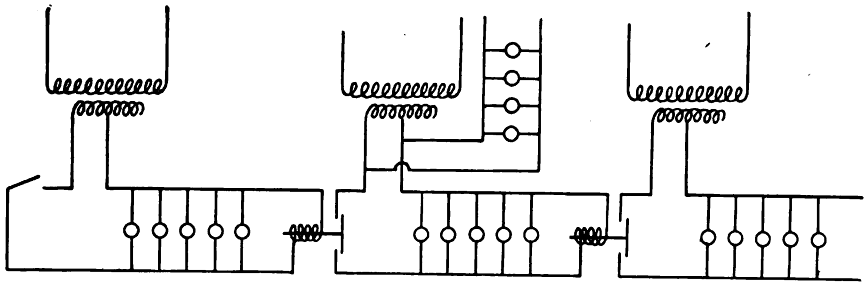

Fig. 4—Cascade Control of Multiple Street Lamps

The so-called pilot wire control utilizes a somewhat different principle for switching the lamps on and off. In this method, as will be seen from Fig. 5, lamps of the system are grouped in sections of suitable size to be controlled by a single switch and the separate switches are operated from a pilot wire which is energized from the sub-station or control point. The pilot wire can obviously be made of low current carrying capacity since it does not carry the lamp current but simply serves to energize the switch relays. Switch relays of several different models have been developed in connection with this pilot wire control. The simplest type consists of a solenoid-operated switch, which is closed or opened, depending on whether the current is on or off the control wire. Preferably, switches of this type should be closed when the pilot wire is de-energized, so that if the pilot circuit is accidentally opened the lamps will all be lighted, even though the break should occur during the daytime and therefore result in some waste of current.

Another type includes a mechanism with on and off positions. With this, the first time the control wire is

energized the lamps are lighted. The next time the lamps are turned off, and so on. Continuous application of current to the control wire is not necessary with this form, but there exists a possibility of lamps being left turned off when it was desired to have them on, or vice versa, due to the switches getting out of step. A pilot or signal switch at the control station has been suggested to obviate this uncertainty. Also, one manufacturer has provided for convenient hand setting of individual switches which might drop out of step.

In an endeavor to avoid the objections raised against the impulse-operated switches of the type just described other forms have been developed which operate from

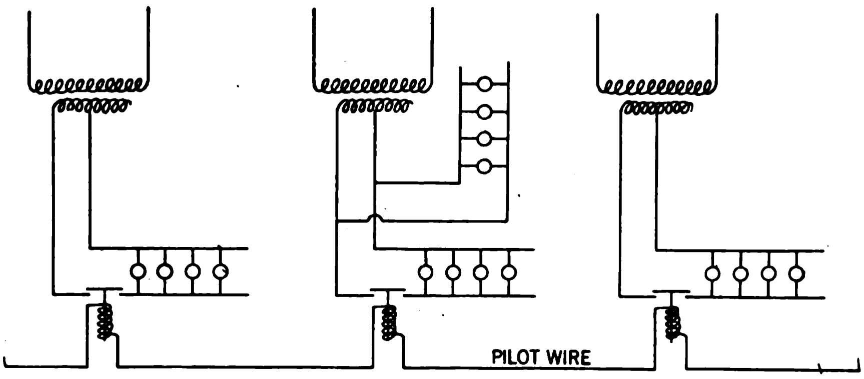

FIG. 5—PILOT WIRE RELAY SWITCH CONTROL

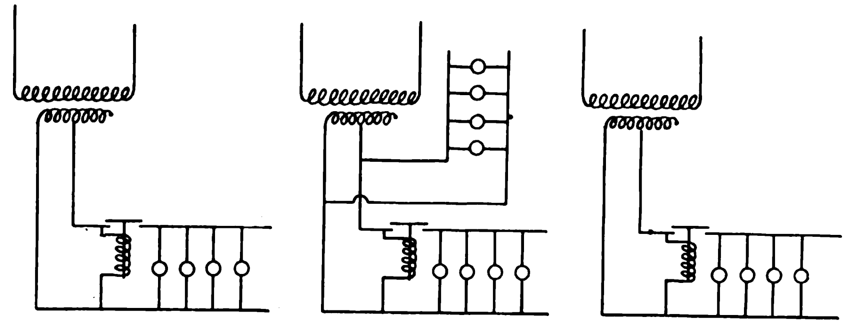

FIG. 6—CONTROL BY AUTOMATIC CLOCK OR IMPULSE OPERATED RELAY SWITCHES WITHOUT SEPARATE CONTROL CIRCUIT

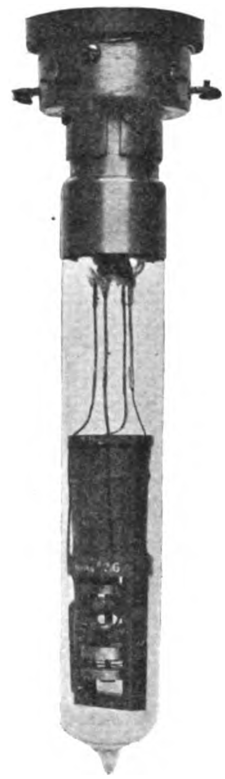

FIG. 7—SMALL RELAY SWITCH OPERATED IN INERT GAS

impulses of different strength. One of this type is illustrated in Fig. 7. The solenoid has two plungers so adjusted that a certain current will lift one and close the circuit. The impression of double this voltage on the control circuit lifts the second plunger which releases the catch and opens the lamp circuit. Such an arrangement using different impulses for the on and off position, has the advantage of avoiding the possibility of switches falling out of step. For instance, when turning on the lamps the control circuit can be given several impulses if desired without fear of leaving the switches in the wrong position.

In order to reduce the wattage required to operate the switch to the lowest possible value and to be able to carry a large number on a single control circuit, the parts are made light in weight. Corrosion and the resultant failure of switches is avoided by sealing the entire mechanism in a glass bulb filled with an inert gas. The capacity of these small switches is limited, but where a heavy current is to be handled they can be used as relays to operate a circuit breaker.

The pilot wires for operating the types of switches described may connect the switches in series. A greater flexibility in making extensions results if the switches can be operated in parallel, and in this case the neutral or grounded side of the distribution system may be used as one side of the control circuit and only one wire need be run to each switch. With a switch which operates on an impulse transmitted at low voltage, a relatively inexpensive galvanized iron wire such as is used in telegraph circuits, will frequently prove satisfactory.

Since the installation of a pilot or control circuit involves a certain amount of inconvenience and expense, considerable attention has already been directed toward the development of a remote-control switch system which would not require extra wiring beyond the necessary extension of the circuit from the feeders to the lamps. One of the earliest devices for accomplishing this result was the clock or time switch. Early designs were often unreliable in operation, and therefore quite unsatisfactory; however, there are available at present, time switches which withstand the severe conditions to which they are subjected. Again, time clock switches may be had which are electrically wound and which may be set to change the time of switching the lamps automatically, according to a

prearranged schedule of burning. Experience has indicated that clocks require a considerable amount of attention and regulation to keep them operating and in close agreement with each other. This factor, together with the question of initial cost, has hindered the more extended use of these devices.

A tiny synchronous motor-operated clock switch requiring an almost negligible wattage, is also available for remote control switching on alternating current circuits. This switch would find its best application in systems whose average frequency is well maintained and where there are but few interruptions of service. Otherwise the switches are liable to require a considerable amount of resetting.

Quite a different and a more satisfying solution of the problem of providing an economical and satisfactory remote control for multiple street lamps would appear to lie in the development of a system of switch controls operated without pilot wires and without clock mechanisms, but so arranged as to be actuated at will from the power station or control point.

One remote control switch now on the market is operated by "winking", or quickly opening and closing the supply circuit. Where the other load carried on the same distribution system is of such character that a momentary interruption of power does not interfere with its operation, this method will work out successfully.

Also, experimental apparatus has been built showing the practicability of operating switch relays by varying the frequency of the alternating-current supply a few cycles above and below normal. The opening and closing of the relay circuit may be controlled simply by the vibration of metal reeds similar to those in the familiar frequency meter, tuned to the proper frequencies. An arrangement of this kind would appear to be practical, at least in smaller communities where there are no serious difficulties attendant upon momentarily changing the speed of the generators.

Different experimenters have proposed also the use of relay switches receiving impulses from wireless waves, though so far as is known, the opportunities of development in this field have not been exploited.

Operation of the switch relays by means of selenium cells has been suggested. The operation of such switches would, however, be entirely dependent on the amount of daylight, and would not necessarily control the lamps according to the fixed hours of burning involved in many street lighting contracts. Furthermore, it would not be possible to turn the system on and off for test or other purposes, except by the additional provision of hand-operated switches.

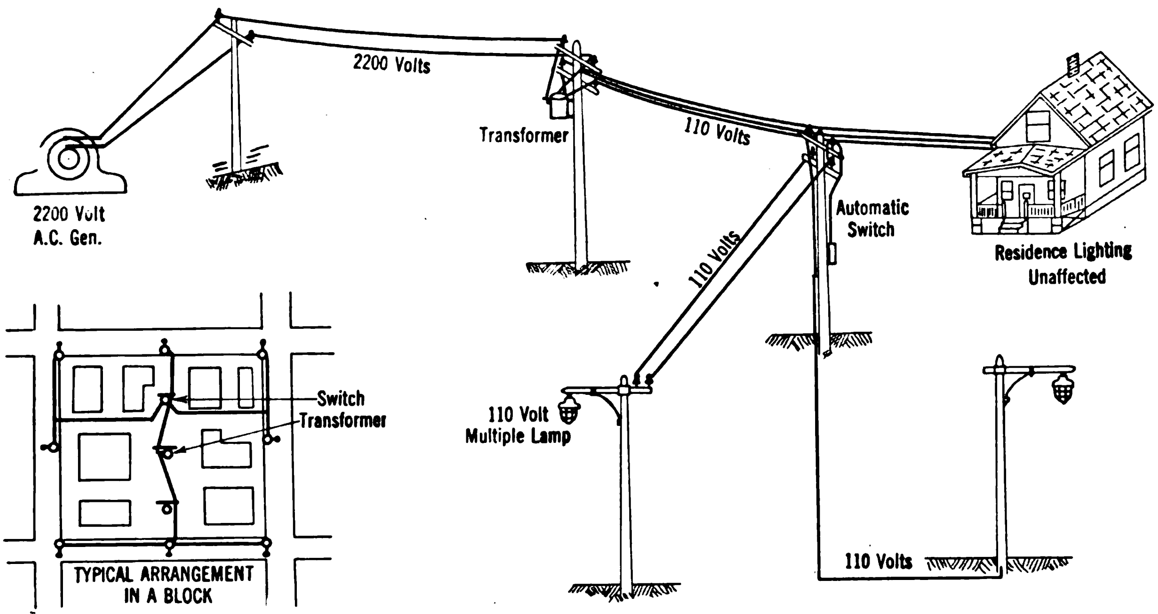

FIG. 8—PLAN OF OPERATING STREET LAMPS FROM SECONDARIES OF A HOUSE LIGHTING SYSTEM

The development of a phantom-circuit-operated control switch has been described elsewhere[1], and with further development this plan would appear to have promising possibilities. At present, however, the expense of the apparatus is too great to permit of an individual control for each lamp.

It seems reasonable to believe, however, that apparatus operated without a pilot wire should soon be developed by means of which street lamps can be lighted and extinguished at will, in a manner which is not open to any of the foregoing objections. At the same time it is evident that such a system, to be successful, must not involve a high cost per unit installed; also, it must not require the addition of any considerable amount of equipment on the 2200 lines; finally, its mode of operation, particularly if it involves the use of high frequency, must be such that there is no possibility of

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injury to transformer insulation or to any apparatus forming a part of the present standard distribution system.

TABLE I.
COMPARATIVE EFFICIENCIES OF GAS-FILLED INCANDESCENT UNITS.

MULTIPLE LAMPS

Watts	Lumens	Lumens per watt
100	1,260	12.57
150	2,040	13.66
200	3,100	15.51
300	4,840	16.11
500	8,750	17.45
750	13,900	18.48
1,000	19,300	19.33

SERIES LAMPS

Amperes	Nominal candle power	Approx. watts	Approx. lumens.	Lumens per watt.
6.6	100	72	1,000	13.96
6.6	250	155	2,500	16.11
15.	400	240*	4,000	16.65*
20.	600	344*	6,000	17.45*
20.	1,000	556*	10,000	18.00*
20.	1,500	809*	15,000	18.55*

*Includes 7 per cent allowance for loss in transformation.

LAMP CHARACTERISTICS

The serious loss in light output when incandescent lamps are operated at less than rated voltage, is shown graphically in Fig. 9. Because of this characteristic it

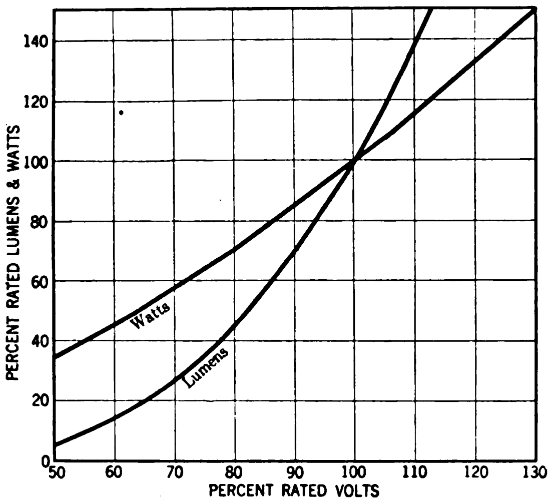

FIG. 9—VOLTAGE, CANDLE POWER AND WATTAGE CHARACTERISTICS OF MULTIPLE TUNGSTEN FILAMENT LAMPS

is essential with multiple systems that lamps be used whose ratings correspond closely to the voltage measured at the socket. In most cases with series systems, the operation of all lamps at proper efficiency is assured if the current is maintained at the correct value at the station. In some multiple installations a large number of lamps may be carried on comparatively long branches, so that there exists a considerable difference in voltage between sockets near the feeders and at the far end. This difference in voltage may become so great that the expedient of using lamps of two or even three different voltages is sometimes followed. Under these circumstances every lamp post must be marked with a symbol indicating the proper voltage of lamp to be used in the replacement of burnouts. In spite of this precaution, however, confusion of lamp voltages is very likely to arise unless the maintenance of the system is supervised with unusual care. A plan which is usually preferable is to provide for a very small drop between the street lamp and the supply circuit by running short branches and operating from one to three lamps on a branch. Table I shows the efficiency of the various sizes of multiple and series lamps computed in lumens per watt. For the 15-and 20-ampere units an allowance of 7 per cent has been made to cover loss in transformation. In Fig. 3 these data have been plotted graphically so that the comparative efficiency of series and multiple lamps of equivalent output may be readily seen. In the case of those series lamps which are available both in 6.6 and higher

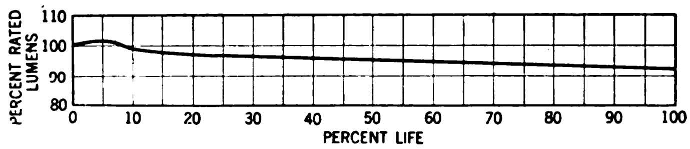

FIG. 10—TYPICAL LIFE-CANDLE POWER PERFORMANCE OF MULTIPLE TUNGSTEN FILAMENT LAMPS

amperages, the more efficient type has been shown. The very slight inferiority of multiple lamps from the standpoint of efficiency is worthy of note.

The depreciation in candle power or falling off in light output during life, is comparatively slight for the modern types of gas-filled incandescent lamps. The curve of Fig. 10, based on life tests of a large number of lamps of the sizes customary in street lighting, illustrates the performance which may be expected.

CONCLUSION

A fundamental reason for the increasing interest in multiple systems for street lighting is the growing realization that with present systems but a small part of the total cost of operation per lamp per year (usually not more than one-third) is to cover the actual cost of light; *i. e.*, cost for current and lamp renewals, or electrodes; the major portion consists of fixed charges on special equipment, floor space rental in substations, and proportionate charges for the use of pole lines and underground ducts. Furthermore, these latter charges are abnormally high per kv-a. owing to the small load carried on the average series circuit. Twenty-three hundred and 11,000-volt multiple circuits may be loaded at 400 to 4000 kv-a., while a 6.6-ampere circuit occupying an adjoining duct, is usually considered fully loaded at 20-30 kv-a.

Audible Electric Signals in Industrial Plants, and Acoustical Engineering

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The paper is a plea for a wider use of acoustic signals in industrial plants. It is shown that much time is wasted by the officials, experts, and important employees in trying to locate each other. With loud acoustic signals installed throughout a plant, in the shops, yards, and offices, it becomes possible to locate any of a considerable number of men instantly, using a simple code call for each. Such calls could be given only imperfectly by pushing a button, and for this reason a special code calling instrument has been developed, which closes electric contacts automatically, after having been set for a desired combination.

The actual conditions and the needs for acoustic signals are discussed in application to steel mills, shipyards, textile mills, printing establishments, coal mines, construction jobs, etc. It is shown that in addition to code calls, audible signals and particularly electric horns are used with advantage as extensions to telephone bells in noisy places, and also as warning signals for various purposes.

The general scope of the forthcoming art of acoustic engineering is then discussed, and its importance is shown in design of theaters, churches, and large auditoriums; also in the installation of fog signals. The problem of measurement of sound intensity is then taken up and the available means and devices are described. It is also shown that sound waves may be directly photographed under proper conditions and the laws of their propagation studied. Attention is called to the importance of experimental and theoretical study of the modes of vibrations of diaphragms used in acoustic devices.

I. The Need for Acoustic Signals

No industrial plant of any magnitude may be considered fully efficient unless means are provided for promptly locating any important employe, no matter where he may be within the plant. A private telephone system, however extensive, serves this purpose only as long as the needed man is at his desk, but as soon as he leaves his desk the problem of locating him becomes a hit-and-miss proposition. On the other hand a superintendent, a foreman, a millwright, a repair man, etc., is ordinarily useful only in so far as he can freely move about the shop without the fear that some one of importance may need him. Thus, within the last few years, under the tremendous impetus of the pressure for an enormous increase in the production of munitions of war, audible electric signals have been introduced into many industrial plants.

Such an electric signal is usually similar in its construction to the familiar electric "horn" used on automobiles. It consists of a diaphragm with an anvil at its center. A toothed wheel driven by a small electric motor strikes the anvil many times a second and causes it to vibrate vigorously. These vibrations produce the well-known warning tone, which carries over a considerable distance. The device is provided with a projector or horn the shape of which depends on whether it is desired to scatter the sound, to intensify it in horizontal direction, or to deflect it downward. Such motor driven signals are now made much more powerful than automobile horns, and are wound for 110 or 220 volts, direct or alternating current, so that they can be connected to a lighting or power circuit, and do not require a separate low-voltage battery.

With such electric audible signals scattered throughout the plant, it becomes an easy matter to locate instantly any person to whom a code number has been assigned. For example, when the manager wishes to speak to one of the assistant superintendents, who may be anywhere in the plant, he simply tells the telephone operator to sound this particular man's call. As soon as this assistant superintendent hears his call, he comes to the nearest telephone, and reports, whereupon the operator connects him with the manager.

It would be rather inconvenient for the telephone operator to sound various calls by hand; therefore a special code-calling automatic instrument has been developed for this purpose. The operator merely sets the desired person's code number on a dial and pulls a lever. A contact-making mechanism is thereby set in motion, which closes the electric circuit and operates the signals throughout the plant the required number of times (usually three times) and then stops automatically.

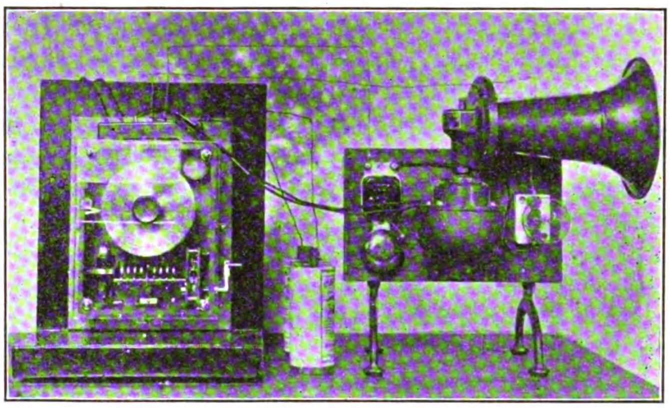


Fig. 1—A Code Calling Instrument (Klaxocator) and the Signals Which It Actuates, viz., an Electric Horn, a Bell, and an Electric Lamp

In noisy and in open places, or in large factory lofts, the electric horns mentioned above constitute the most

*Presented at the Rochester Section A.I.E.E., April 25, 1919, and the Erie Section, May 13, 1919.

suitable type of signal. In offices they may be replaced by less loud electric gongs, bells, buzzers, air whistles, or incandescent lamps. In some cases two separate circuits are run from the code calling mechanism, one circuit for ordinary calls, the other for fire-alarm gongs, or for some other special purpose. Sometimes two allied plants are operated side by side with a separate staff in each. Then the same code combinations can be assigned in both plants, but the horns in one or the other plant will sound according to which of the two circuits is closed.

A further application of loud electric horns in industrial plants is for extensions to telephone bells. The ordinary telephone ringer is not loud enough in many shops, when the foreman is away from his desk. In this case, a relay is connected in parallel with or in place of the telephone ringer, and when it is actuated, it closes a secondary circuit which causes an electric horn to sound. This call should be a single blow to distinguish it from code calls.

Audible electric systems are also used in various plants as warning signals on cranes and hoists, also to call a shifting locomotive, to indicate the beginning or the end of a certain operation, and for other local purposes. As in the case of any other convenience, once such an electric signal system has been installed, the superintendent, the foreman, and even the operatives themselves will find new uses for it.

II. Various Industrial Uses

1. *Steel Mills.* Of all types of industrial plants steel mills have buildings scattered over a particularly large area, with wide yards between. Taking into consideration also the noisy character of such mills, the importance of acoustic signals will become at once apparent. The three kinds of signals to be considered are:

a. Code calls for important employes.

b. Extensions to telephone bells in noisy places.

c. Warning signals on cranes, local signals at furnaces, rolls, etc.[1]

The large capital involved in the production of steel, the necessity for high-priced experts, and for a very rigid organization, all these factors make the installation of an efficient code calling system almost imperative; the trifling expense involved is entirely insignificant in comparison with the beneficial results achieved.

Now that such a code calling system is available, it is almost incredible that a large steel plant should continue in operation, without any provision whereby the important members of the staff could be instantly put into communication instead of playing hide and seek with each other. If one could compute the loss in production and the increased overhead charges, because of such delays, the figures would be unbelievable.

2. *Shipyards and Structural Iron-works.* Shipyards are not much different from steel mills in so far as the needs for acoustic signals are concerned, with the added problem of inconvenience of direct communication between two parts of a ship hull or between two ships under construction. Therefore it is essential to have a more elaborate code, telling each important man not only that he is needed, but also where he is to go, and whether or not it is an emergency call. This saves a great deal of climbing of stairs and ladders, and permits the overseeing force to utilize their time much more efficiently.

3. *Textile Mills.* Audible signals are essential in a textile mill on account of the great deafening noise of hundreds of high-speed machines and spindles used in many departments. Since telephones are practically impossible in such noisy shops, and since the code system is here needed only for a comparatively small number of superintendents and engineers, each person should be given two or three code numbers, in order that he may know where to go, what to do, and how urgently he is needed. In view of the large number of women and minors employed in the textile industry, fire-alarms should be particularly efficient, and the code calling instrument can be readily provided with a second circuit for sounding fire-alarm gongs, instead of horns. This provision may be in addition to the compulsory independent fire-alarm system, to insure more safety or to give supplementary information as to the location and extent of the fire. The huge Clark Thread Mills in Newark, N. J. are provided with electric horns for fire-alarm purposes, and the installation has operated satisfactorily for a number of years.

4. *Printing Establishments.* The character of work in a large printing establishment is such that the production manager, the man in charge of the machinery, and a few other experts have to cover several floors. The amount of work which they can accomplish depends essentially upon their ability to get in touch with each other, and upon the facility with which their superiors can locate them. A code calling system is therefore an essential adjunct in such a plant, and the signals employed vary from powerful electric horns in noisy press rooms down to gentle buzzers in the offices. A complete system of this kind has been in successful operation for some time in the large printing establishment of P. F. Collier & Son in New York City, which prints the well known weekly, and hundreds of thousands of copies of various books. One feature of this installation is that the code calling instrument is placed at the desk of a clerk, in the production manager's office, and the telephone operator has nothing to do with it. The local conditions are such that it seems desirable to limit the use of the system to important calls only, and to prevent clerks and office-

1. A number of electric horns are used on cranes, and for calling certain locomotives in the large steel mills of the Jones & Loughlin Co. in Pittsburgh.

boys from calling high-priced men on trifling occasions. The clerk in charge of the code-calling instrument ascertains the nature of the need, before setting the instrument in motion.

5. *Coal Mines.* A modern coal mine may have miles of passages and rooms underground, so that the superintendent, his assistants, the master mechanic, the electrician, etc. have to cover quite an extensive area. The superintendent of an old mine near Pittsburgh once stated to the writer that it might require half a day to locate him. In some states the law prescribes mine 'phones at the main workings, and this requirement makes a code calling equipment so much more important. The superintendent may be half a mile away from the nearest telephone, and could not possibly hear it or know whether he or someone else is wanted. A system of powerful horns installed throughout the mine and connected to a code calling instrument outside the mine would instantly convey the call and then the superintendent or whoever is called would come to the nearest telephone and report to the operator.

A further improvement of this system might consist in providing the superintendent, the foremen, the electrician, etc. with portable telephones, which could be connected to the line wires at any point. This is possible in many mines in which bare steel wires are used for the telephone circuit. In some mines, especially where rope haulage is used, the man on the train is given a piece of metal with which he short-circuits these two wires and causes a signal gong to ring at the winding engine. In this case the telephones are connected through condensers, and electrical connections are used similar to those which permit simultaneous telegraphy and telephony over the same wires. The same acoustic signals may be used for sounding emergency calls or for a general alarm, although the exact arrangement would have to be worked out separately to meet the conditions in each individual mine.

6. *Construction Jobs.* Audible signals could be made useful on large construction jobs, scattered over a considerable distance, for example, on large buildings, hydraulic dams, power plants, bridges, aqueducts, transmission lines and the like. Such audible signals may be used either in conjunction with temporary telephones, or without them. Where telephones are available, the audible signals merely serve to call the desired person to the nearest 'phone, no matter where he may be located. Without telephones, a more elaborate code may be needed, so that two persons could actually transmit simple information by blowing their horns. Where an electric power distribution is not available, horns could be operated from 6-volt storage batteries, or even from a few dry cells. Hand operated diaphragm horns are also available in which sound is produced by turning a crank by hand. A number of such hand-operated horns have been used in the trenches during the late war, especially for warnings of an approaching gas attack.

7. *Marine Applications.* The hazards of the sea today demand an equipment which will not alone fill the needs of routine service, but which will also prove unfailingly efficient under the stress of emergency. The intercommunication and signal equipment is the nerve system of the ship. During emergencies it becomes the one and only means which enables the officers to direct and coordinate the operations of the ship and its crew. Upon the signal equipment may depend the ship's safety. Voice tubes, gongs, whistles, etc. find their place, but for some purposes powerful electric horns are indispensible. A large number of such horns have been recently installed on various U. S. naval vessels. They can be used as a warning of hazards, as fire-alarm signals, for general alarms, as hoist signals, and also for code calls throughout the ship.

Another use which has not received sufficient attention is for communication between ships at a short distance from each other, or between a ship and the shore. Audible signals should have a distinct useful field for distances beyond the carrying power of the megaphone, and where wireless communication is not available. They can be operated at a much higher speed than an inconvenient and sluggish steam whistle, which moreover is supposed to be sounded for other purposes.

8. *Large Public Gatherings.* At large national conventions, festivals, and other public gatherings, there is often a need for promptly locating an official or a prominent guest in the crowd. This can be done in many cases by using audible signals, supplementing them where necessary by electric lamps, or other visual signals. For example, the chairman of an important committee or the secretary of the convention may be in any of the meeting rooms, in some committee room, in the lobby, or playing golf. Should the president or the chairman need him, his code call could be sounded throughout the grounds, and he could be located within a short time. Also any member of the convention who expects an important telegram or a long-distance call, may be given a code number and then he could move freely throughout the hotel with a confident assurance that he would know instantly when he is needed.

9. *Hold-up Alarms for Banks.* With a masked man pointing a revolver at him, about the only thing that the teller could do is to press a push-button with his foot. According to the local conditions, an audible signal connected to this push-button would cause an alarm to sound at the next street corner, where a policeman may be located, or in some large establishment nearby in which certain men have been trained and armed for such an emergency. Whatever the details this is a new application of audible signals well worth looking into. The problem is to prevent the hold-up men from getting away in the automobile, which usually waits for them outside.

III. Architectural Acoustics

The acoustic problem with which architects are concerned in large auditoriums, theaters, churches, etc. is that of proper audibility. A sound produced on the stage, be it a spoken or sung vowel, or the sound of a musical instrument, is propagated through the air, until the wave strikes the walls, the ceiling or any objects in the auditorium. Here the sound wave is partly reflected, partly absorbed by the material and a small part may even be transmitted outside. The reflected waves travel back and forth and are reflected several times before their energy has been completely spent and converted into heat. This nature of propagation of acoustic waves gives rise to several phenomena, mostly disturbing from the hearer's point of view. Thus the direct and the reflected wave may be out of phase with each other, and produce a weakening of the resultant sound (interference) at some points of the auditorium. At other points an undue strengthening (consonance) may take place. The reflected waves continue to be audible for some time after the source of sound has ceased, and they produce that annoying indistinct noise known as *reverberation,* which makes it difficult to follow a speaker. Again, *echoes* may be troublesome in some parts of the auditorium. A sharp short note instead of being heard once may be audible two or three times, spoiling the musical effect.

The foregoing problems and their effect upon the design of auditoriums and theaters have been treated quite thoroughly by the late Professor Wallace C. Sabine of Harvard University.[2] He made numerous tests on the relative absorbing power of different substances using organ pipes as the source of sound. The duration of the audible sound after the pipe has ceased was determined with a chronograph, and taken as a measure of reverberation. In one of the tests in a theater he obtained the following results:

empty, without seats...........	5.62 seconds
empty, with cushion seats.......	2.03 "
filled with audience............	1.14 "

He then introduced into the auditorium different absorbing materials, and by elaborate experiments and computations found the absolute values of their absorption coefficients, that is, percentages of the incident sound intensity that they neither reflect nor transmit.[3]

Using the correct values of coefficients of absorption, and knowing the velocity of sound in the air (about 1132 feet per sec. at 70 deg. fahr.) one can estimate the actual acoustic conditions at a given point in an auditorium, by a somewhat tedious process of construction similar to that of geometric optics. Prof. Sabine has also applied the well-known method of photographing sound waves to the determination of the acoustic conditions in an auditorium. He made small models of certain theaters, produced sound waves in them by means of an electric spark and photographed them by illuminating the wave fronts with another electric spark.[4] In this way it became possible to judge about the acoustic qualities of a projected auditorium with a considerable degree of accuracy, or to find the cause of faulty acoustics in a given hall.

Similar problems will probably arise in industrial plants and in other places in which acoustic signals will be gradually installed as a necessary adjunct for an efficient operation. In plants with complicated structures and machinery we shall find zones of silence or of reduced audibility; we may have to solve problems of reverberation and of echoes in places like a coal mine, and it will be necessary to determine the absorbing power of the principal materials and objects met with in an industrial plant. Fortunately, physicists and architects have done some splendid ground work in this direction, and acoustic engineers will mainly have to apply their methods to somewhat different structures and conditions.

IV. Measurement of Sound Intensity

If acoustics is to become a branch of applied science or engineering, the physical quantities involved, particularly the sound intensity, will have to be measured in some simple units and by means of a simple and robust instrument. A steam engine is guaranteed to develop so many horse power at a certain speed; an electric lamp is sold to give so many candle power in a certain direction. So in time an electric horn may be guaranteed to produce a sound intensity of so many "carusos" per square centimeter, at a distance of say one hundred meters from its diaphragm. At least the trend of the development in other branches of engineering has been from inaccurate and confusing notation by trade-names and by arbitrary numbers, to accurate specifications based upon physical units. Sound waves represent a certain mechanical energy, and therefore their intensity should be measured in energy units per square centimeter of area perpendicular to the direction of propagation. Of course, the question of selective sensitiveness of the human ear must also be considered, and the energy measured only within the audible range; the range of maximum sensitiveness of audibility lies between 700 and 3000 vibrations per second. Thus, when the candle-power of a search-light is specified or

2. See for example his article on Theater Acoustics, in the *American Architect,* Vol. 104 (1913), p. 257, and on Architectural Acoustics, in *The Building News,* Vol. 108 (1915), p. 180. Numerous references to other investigations will be found in these articles.

3. For other investigations on the transmission, reflection and absorption of sound by different materials, see F. R. Watson, *Physical Review,* Vol. 7 (1916), p. 125; H. D. Taylor, *Physical Review,* October, 1913; C. S. McGinnis, a thesis presented to the University of Pennsylvania, 1911.

4. For actual photographs see the references to his articles above. The method is described below under "propagation of sound."

measured, only the rays within the visual range are considered, and no credit is given the maker for ultra-violet or infra-red rays.

Just as with the progress of electric lighting of large spaces the need arose for simple portable photometers to measure the intensity and distribution of illumination, so in time we shall need simple practical devices for measuring sound intensity, produced by an acoustic signal, and its distribution in space. Such need has already been felt in connection with fog signals in which the volume of sound possible with one siren is limited as compared to the wide areas over which it must be heard under adverse conditions of wind.[5]

A simple indicator of sound intensity is the so-called Rayleigh disk which is a small and light vertical disk suspended freely on a fine quartz fiber and placed at an angle of about 45 deg. to the direction of the sound. When sound waves impinge upon it, it has a tendency to place itself at right angles to the direction of their propagation. The sound intensity of the waves may be computed from the observed angle of torsion.[6] In spite of this apparent simplicity this method has not been used much in practical acoustical measurements.

An instrument of considerable accuracy and sensitiveness for measuring sound intensity at a point is the *phonometer*,[7] developed by Dr. A. G. Webster of Clark University. It consists of a hollow cylindrical chamber (an adjustable Helmholtz resonator), one end of which is in communication with the atmosphere, and the other end is covered by a mica piston held in place by three stretched strings at 120 deg. to each other. The resonator is tuned to the pitch of the incoming sound, so that the impinging waves set the mica piston into vibration. The amplitude of vibrations is measured by means of a tiny mirror and a telescope on a scale. The vibrating system which consists of the three strings with a central block and the mica piston must also be tuned to the frequency of the incoming sound.

Some satisfactory measurements of sound intensity have been also made with a sensitive telephone receiver mounted on an intensifying resonator in front of it. Within certain limits the alternating current induced in the telephone receiver windings by the vibrations of its diaphragm, is proportional to the sound intensity, or at least a calibration curve may be obtained between known sound intensities and corresponding currents. The induced currents are exceedingly small and can be measured by the following two methods:

a. Using a crystal rectifier[8] and a d-c. galvanometer of high sensitiveness.

b. By means of a very sensitive vacuum thermo-couple.[9]

All these methods are reliable only with pure sounds of a single pitch, and the devices must be tuned to that pitch. Prof. Miller's *phonodeik*, which is a diaphragm device, responds to a considerable range of frequencies, and gives a photographic record of a complex sound wave. Unfortunately it distorts the relative magnitudes of the harmonics because of the resonant frequencies of the diaphragm itself; somewhat tedious corrections are necessary in order to reconstruct the actual sound wave.[10]

It will be seen from the foregoing, that the difficulties in measuring sound intensity are greater at the present time than those attending the measurement of the intensity of light from ordinary illuminants. It is to be hoped that the coming need for practical measurements of sound intensity will lead to a speedy development of a convenient measuring device, even though of moderate accuracy.

The fact that an industrial signal is intended for the human ear, and not for a measuring device, must not be lost sight of. An inanimate receiver tuned to a certain frequency may indicate a sound of great intensity which the human ear may not be able to distinguish from the din and howl of machinery. Systematic experiments will be needed on the sensitiveness of the human ear not only to sounds of different pitch, but to the same sounds accompanied by disturbing noises, simultaneous or in succession, continuous, interrupted, increasing or decreasing in intensity. Only a beginning has been made in this direction.[11]

V. Experimental Study of the Propagation of Sound Waves

A field of many possibilities in practical experimental acoustics has been opened, due to the development of a method for directly photographing sound waves. This method has been brought to a considerable degree of perfection by Prof. A. L. Foley of Indiana University.[12] In this method, use is made of the fact that a sound wave consists of consecutive condensations and rarefactions of the air, so that the density of the air in the wave front is different from that just ahead and just behind it. Therefore, if a moving sound wave be instantly illuminated with an electric spark, light will

5. For an excellent example of the use of a sound-measuring instrument, *viz.* Webster's phonometer, in the study of the distribution of sound from a siren see L. V. King, Acoustic Efficiency of Fog-Signal Machinery, *Journal of the Franklin Institute*, 183 (1917), p. 259.

6. See Barton, A Text-Book on Sound, p. 365; also Philosophical Magazine, Vol. 14 (1882), p. 186.

7. See *The Absolute Measurement of the Intensity of Sound*, A. G. Webster, PROCEEDINGS A. I. E. E., July 1919, p. 889.

8. G. W. Pierce, Proc. American Academy 43 (1907), No. 13.

9. F. R. Watson, *Phys. Review*, 30 (1910), p. 471; H. S. Osborne, Proc. A. I. E. E., Feb. 1919.

10. D. C. Miller, The Science of Musical Sounds, Macmillan, 1916, pp. 78 and 142.

11. A. P. Weiss, Apparatus and Experiments on Sound Intensity, Psychological Monographs, Vol. 22, 1916.

12. *Physical Review*, Nov. 1912.

be refracted at the places corresponding to the wave front, and an image could be obtained on a photographic plate. Foley used an electric spark as a source of sound, and another spark for illuminating the wave front of the sound produced by the first spark. The two sparks must be accurately timed, in order to catch the wave front in a desired position.[13] Dr. Foley has demonstrated in this manner a concentric wave from a point source, its reflection from a plane surface, and from a convex mirror; refraction of sound waves by acoustic lenses filled with different gases, the action of a diffraction grating, and some other fundamental phenomena in the propagation of sound waves.

These researches not only gave an experimental assurance to the purely theoretical statements of the fundamental laws of acoustics, but they also furnished a method for an experimental study of sound waves, under conditions which are too complex for theoretical computations. Dr. Sabine has applied this method to the solution of acoustic problems in some theaters. He made a small model of each theater, representing its cross-sections in a vertical and in a horizontal plane, and produced sound waves within each model at the stage by means of an electric spark. Photographs taken by means of another spark clearly show various trains of reflected waves, and the existence of conditions conducive to the formation of reverberations and echoes. By suitably changing the proportions, Prof. Sabine was able to improve the acoustic conditions on the model, and consequently was in a position to recommend with a fair degree of assurance, similar changes to be made in the actual theater.

It is quite possible that this method may prove to be of utility in the solution of similar acoustic problems in industrial plants. Photographs taken on models of complicated ship-yards, coal mines, or a mill full of machinery may explain some observed abnormal conditions such as zones of silence and a departure of the sound intensity from the simple law of inverse squares.[14]

VI. Diaphragms

A diaphragm is the most essential part of an electric horn; it is also an important organ in the telephone receiver and transmitter; it enters in the construction of the phonograph and other sound reproducing devices; it can be used for sound measurements, and it is also the sound receiving part of the human ear. For these reasons, numerous investigations, experimental and theoretical, have been made on all kinds of diaphragms and membranes.

As early as the eighteenth century, Chladni experimented with diaphragms of various shapes by putting a little sand on them and setting them into vibration by a violin bow. The sand is immediately driven away from the parts which are violently vibrating to places which are comparatively quiet. The resulting sand figures clearly indicate the shape of the segments into which the diaphragm is divided. The same diaphragm can be made to vibrate in a number of different modes by suitably holding it with the fingers, and bowing at different places. An account of Chladni figures may be found in almost any standard text-book on sound.[15]

A large number of investigators have worked experimentally on the study of vibrations of telephone diaphragms. In many of these researches a very small mirror was attached to the diaphragm, which mirror reflected light from a powerful source upon a scale on which the vibrations could be read directly.[16]

Some investigators have obtained direct photographic records of vibrations,[17] and a few attempts have been made to reflect light directly from a highly polished diaphragm. Observations have also been taken through a microscope of a stylus attached to the diaphragm.

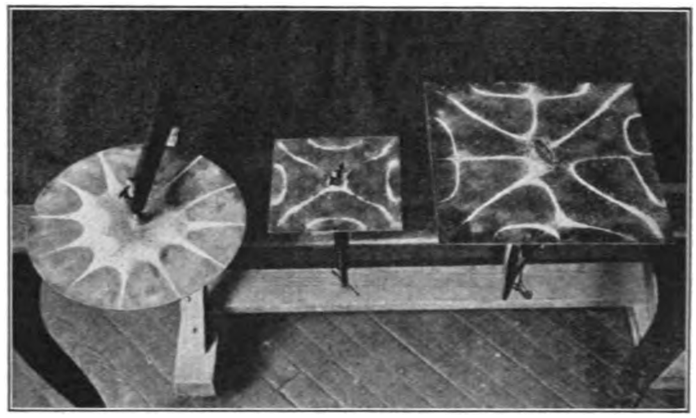


Fig. 2—Sand Figures Produced by Vibrations of Round and Square Plates, Showing Nodal Lines

Future improvements in signal horns and in telephone apparatus will largely depend upon our better knowledge of the modes of vibrations of diaphragms. In an acoustic signal we try to vibrate the diaphragm at one of its natural frequencies, so as to get as nearly as possible a pure tone, with a minimum of excitation. In a telephone receiver or transmitter, or in any other speech-reproducing device, the natural frequencies of the diaphragm constitute a disturbing factor, which gives it a selective sensitiveness for certain frequencies only.

13. A number of lantern slides were shown at the lecture giving results of Dr. Foley's experiments, and also some photographs of sound waves in auditoriums, taken by Prof. Sabine.

14. Dr. G. D. Shepardson, Telephone Apparatus (Appleton, 1917), p. 9; John Tyndall, Sound (Appleton, 1876) p. 287; A. Mallock, Proc. Roy. Soc., Part A. 91 (1914), p. 71.

15. A number of sand figures were demonstrated during the lecture using round and square plates.

16. For a fairly complete bibliography of these studies see E. A. Kennelly and H. Nukiyama, Proc. A. I. E. E., Vol. 38 (1919), p. 538.

17. A. Guyau, Le Téléphone, Instrument de Mésure (Gauthier Villars, 1914), p. 59.

The problem is further complicated by the fact that the diaphragm is seldom used alone, but usually has a horn (projector or mouthpiece) associated with it. This horn adds its natural frequencies due to the enclosed air and thus modifies the properties of the diaphragm itself. Besides, there are unavoidable little cavities where the diaphragm is built into a housing, and these cavities act as resonance chambers, adding to the troublesome selective sensitiveness of the combination.

A systematic study of these factors is still in its infancy, and offers a big and fruitful field for the future investigator.

The author wishes to express his appreciation to Klaxon Company, Industrial Division, and to its manager, Mr. E. Berg for their assistance in this investigation, and for the loan of apparatus, used at the presentation of the paper. He is also under obligation to the managers and electrical engineers of various industrial plants for the opportunity and facilities afforded in the study of their signal installations and acoustic conditions.

The Indispensibility to Each Other of Pure and Applied Science

BY H. A. BUMSTEAD
Professor of Physics, Yale University

I ACCEPTED, with considerable hesitation, the invitation to address you on the general subject of the relations of pure and applied science; and in particular of physics and engineering. Two years ago, Colonel Carty in his presidential address to the A. I. E. E. spoke upon this subject in a way which met with the hearty approval of all physicists. He has done more than most to foster cooperation between us and to bring about great practical results by utilizing the method of scientific research. What is there left for me to say?

One thing that I want to say is that Colonel Carty in his addresses has very generously acknowledged the debt which applied science owes to what is called pure science, and I wish to emphasize the reciprocal obligation. There is the obvious indebtedness for improved and convenient apparatus, material and machinery. How fast should we get on if we had, like Faraday, to insulate our own wire and make electromagnets out of links of anchor chain? The co-existence in cooperation between the two phases of science, which we call pure and applied, is of the very essence of the spirit and method of modern science, and is necessary to its existence.

When one speaks of modern science, one means, I think, essentially the method of planned and reasoned *experiment*, and, with a few sporadic exceptions, systematic experimentation was practically unknown until about 350 years ago. It marks a very great epoch in human history.

We are not far wrong in dating this great epoch from Galileo. Now Galileo begins his "dialogues," which have recently been published, by remarking that the workmen in the Venetian arsenal must have experienced many things that would be worthy the attention of philosophers. In fact, he takes as the foundation of his great and revolutionary theories, the experiences of the shop and the shipyard. And this attitude has been characteristic of the greatest men of science from that time to the present. In fact, since the time of Archimedes, there have not really been two streams of science, as we sometimes assume, but two aspects of the same thing, which I believe cannot be really separated. I think we may recognize in some sense the helplessness and sterility of either without the other, by considering two periods in the history of the past.

The Romans were probably the most narrowly practical people in the history of the world. They were great engineers, they covered Europe, Western Asia, and Northern Africa, with magnificent roads, and built bridges, acqueducts and great buildings, many of which are still in good repair, after nearly or quite two thousand years. They were wonderful adapters of known things to useful purposes; but, so far as I know, they never originated anything; never discovered anything. They were great lawmakers, but never discovered a single one of those more important "laws" which rule the physical processes of the universe. They went as far as they could go in technical matters without new discoveries. Then there was nothing to prevent the barbarians catching up with them in these things; and as they had not become degenerate through centuries of luxury and selfishness, Rome could not stand against them. I think we may see from the great experiment made by the Romans that a policy of narrow practicality, while temporarily successful, carries with it no promise for the future, and in time defeats its own ends in a great collapse.

On the other hand, it seems to me that the Middle Ages affords us a demonstration that there is such a thing as being too theoretical. Medieval scholasticism produced men of great intellectual ability. They had sound logical minds, daring imaginations, and many of them were most unselfishly devoted to the pursuit of truth. But they despised common things—gross matter, the vile and sinful human body, and in fact, the whole wicked and provisionally damned world. And they, too, reaped the reward of their narrowness. As in the case of the Roman engineers, they arrived at

Abstract of an address before a joint meeting of the A. I. E. E. and Am. Phys. Soc., Philadelphia, October 10, 1919.

some results of real value; but, out of contact with the external world, they soon ran out of material, and an intellectual revolution was necessary to free the human mind from the trammels of their system.

The same sort of thing would happen to physicists and engineers in a generation or two, if a wall could be built between us to shut out from each group the knowledge of what the other group was about. Fortunately, such a wall is impossible; and, short of an entire collapse of civilization and return to barbarism, one can see no reason why our fertile and beneficial cooperation shall ever again cease.

We must, of course recognize the limitations of possible cooperation; it does not mean coalescence. Colonel Carty pointed out in his address, to which I have referred, the difference in the motives which actuate the two groups in their researches, and the necessity for both motives. Each one of us has his own field to cultivate and must in general stick to it for the good of the whole. What we ought to do is to stick to our own jobs, but always be ready and anxious to help each other. There should always be some specially qualified "liaison officers" between us. Lord Kelvin is the archetype of the qualities needed for such service" and while we cannot hope to have a Kelvin in every generation, we have fortunately in this country a strong body of men whose interests and work lie in the borderland between pure and applied science. There have always been some university men of this type; and in the past decade or two, we have seen the development of industrial research laboratories whose personnel forms a natural and very effective bond of union and channel of communication.

As Col. Carty has pointed out, applied science has come to the happy state of being financially self-supporting, and more; while pure science from the nature of the case, never can be. Any aid which the industries can give to pure science, whether by endowments in universities and research institutions, or by supporting pure research in their own laboratories, will be most gratefully recognized by its devotees, and will no doubt bring great returns to the donors, though they may be sometimes long delayed and difficult to trace.

We, on the other hand, especially those of us in university work, have a reciprocal duty, to provide well-trained men for industrial research. In America this duty, up to the present, has been performed, I fear, very imperfectly. The defects have not, I believe, been so much in our graduate schools and doctor's theses as in the undergraduate colleges and schools of technology, to say nothing of our more elementary schools. Our whole educational system is too much permeated with softness,—we are too prone to put our trust in "get wise quick" schemes. Students are helped too much and taught too much, and unless they are of exceptionally good stuff, they get intellectually flabby, and are afraid to face the real difficulty alone.

Another short-coming of both colleges and technical schools in America is the scattering of the student's attention among many subjects of study. In academic colleges, under the elective system it often reaches the point of absurdity, but there is one redeeming feature: A student who knows his mind, or is well-advised, can get a good education by concentrating upon one or two subjects and attaining the beginnings of mastery—the only process by which we become educated either in school or, as happens to most of us, after we leave it.

Even in technical schools, I think we give too much time to many different small subjects under the misapprehension that a boy must be "taught" every separate thing that he will ever need to know. If we could give him a really thorough fundamental knowledge of fundamental subjects, not quickly and easily, and painlessly, but by good hard slugging, he would be in much better position to learn by himself the one thousand and one details that he will need to know in after life.

Whether or not this kind of education would be better for the practicing engineer, I have no doubt, that it would be much better for the man who is to engage in industrial research. And if a different training is needed for the two classes, then it is high time that undergraduate courses should be established along those lines, and that young men should be informed that a comparatively new profession is open to them which promises great rewards in usefulness, and reasonable ones in money to properly qualified men.

Dr. Jewett has pointed out in his admirable Toronto address, the one greatest need of industrial research is properly qualified men; there is plenty of money and plenty of apparatus, but an adequate supply of men is lacking: Not geniuses, but just competent, well-trained men. And the same shortage is very increasingly felt in pure science also.

We need, therefore, to secure public recognition for a comparatively new profession—that of scientific research, with two branches, one in the industrial field, and one in pure science. We must secure an adequate, but no extravagant financial return for those who practise this profession successfully; That is already partly accomplished in the industrial field, and all hope that it will not stop there. We must see that much better training is provided than has been the case in the past.

Finally we must advertise the new profession sufficiently so that young men of a suitable kind may be induced to enter upon this course of training.

In all these things the members of both of our societies can be of enormous assistance. It is a task well worth the doing; for its successful accomplishment will be of incalculable benefit to the world, both materially and intellectually.

The Technical Story of the Synchronous Converter

BY B. G. LAMME

Chief Engineer, Westinghouse Electric & Mfg. Co.

This is intended to be a semi-historical treatment of the engineering development of the synchronous converter as the author saw it. This development occurred over a long period of years and much of this was done inside of the electrical manufacturing companies, rather than in the operating field. In consequence, the many stages which eventually led to the great success of this type of electrical machine are but little known to the electrical public. The various steps in the development are described, covering many of the earlier troubles, and methods tried for overcoming them. The early evidences of hunting which eventually led up to the use of copper dampers; e. m. f. regulation; 60 cycle converters with their ups and downs and final success; the three-wire converter; the inverted converter; the application of commutating poles; the coming of the synchronous booster and the split pole types of converters,—all appear in the story, along with little incidents connected with the engineering and commercial side of the growth. Much of the material of the paper is given directly from the author's memory, checked at times by such technical data as were available. Representing principally the author's personal contact with the development, the story naturally cannot be considered as covering competitors' apparatus except in a very casual way. Errors of omission may thus be numerous, though unavoidable.

THE history of the development of the synchronous converter is comprised, almost entirely, within the inside records of a few of the large electrical manufacturing companies. The reason for this is partly that synchronous converters, since the first, have been built mostly in comparatively large capacities, and in connection with power and transmission systems which have been initiated only by a few of the larger companies.

From the operator's and the electrical "layman's" standpoint, the synchronous converter always has been a fairly well perfected piece of apparatus, without much history connected with it, except, possibly, from the 60-cycle standpoint. Just to look at it, it would appear to be a very simple piece of apparatus in that it is merely a direct current generator with polyphase collector rings attached at suitable points in the armature winding. In general, there was not much "field" development connected with it; that is, it appeared to be a fairly well developed piece of apparatus when it left the manufacturer's hands. However, the fact that many manufacturing companies, both in America and in Europe, made sporadic attempts to put converters on the market with more or less ill success, indicates that one had to "know how," in building converters, just as in other kinds of electrical apparatus. The fact is, that those companies which did succeed in making successful converters, attained success only through certain very expensive developments and much bitter experience, a considerable part of which is not known outside of the manufacturers themselves.

The writer feels competent to discuss this subject freely because he was one of the earliest in this field, and personally went through many of the principal troubles which developed in this line of endeavor. In fact, he believes that he was "over his head" in troubles with converters a considerable while before anyone else even knew that any serious difficulties existed. It is possible that if the manufacturers of converters in the early days had had any true conception of what difficulties would be encountered, they would have dropped the development altogether. Fortunately, they did not know what was coming until they were into the mire so deep that they had to fight their way through. However, as the manufacture of such apparatus has been largely in the hands of the two larger companies in this country, there was no very general public knowledge of the difficulties with which they were confronted. That there was recognition of the difficulties in the development of converters by manufacturing companies in general is indicated by the conditions the writer found in Europe about twenty years ago. At that time in America the 25-cycle synchronous converter was well established and the 60-cycle machine was making a brave attempt to obtain a foothold. He found that almost no manufacturers of electrical machinery in Europe, outside of those with close affiliations with the two larger American companies, were advocating or building synchronous converters to any extent. In answer to all requests for reasons why, he was told that they did not believe in them. However, later, the designers of several of the larger European companies told him that the problem of the development of 50-cycle converters presented such difficulties, that they hesitated to undertake the task, and they were even doubtful about undertaking 25-cycle converters. They admitted that they believed the American converters were quite successful, but that this was only accomplished through most difficult development and at high expense.

It may be mentioned at this point that these difficulties were not all inherent in the converter itself, but were due to a considerable extent, to the characteristics of the power systems to which it was connected. It has had to suffer on account of the sins of its near relations, so to speak. In its successful development, it had to incorporate within itself means for overcoming the difficulties due to the supply systems. Hunting, for instance, is initiated in the generating or transmission systems, as a rule, but the remedies, in general, have been applied to the converter itself. In other words, it not only has had to overlook such troubles in its associates, but, for best results, has had to reach back and partly suppress, or overcome them. Tak-

To be presented before the St. Louis Section, A. I. E. E., January 28, 1920.

ing all in all, it has been a "good-dispositioned" machine, so to speak, or it would have "quit flat" under some of the impositions against which it has labored.

Its coming was not glorified by any great publicity, nor by numerous complex technical or mathematical papers, but it simply grew up without attracting an undue amount of notice, and in fact, it was almost grown up, as far as the 25-cycle frequency was concerned, before the public had fully grasped its presence.

Coming now to the story of the synchronous converter itself, there is some question as to who actually suggested the earliest machine. The writer fully believed, in 1890–91, that he had devised a new and novel apparatus when he worked up the design specifications for an operative machine, but the records of the Patent Office said he was anticipated by Charles Bradley by some two or three years. However, the writer does not know whether Bradley ever built what might be called a commercial machine.

The early design of the writer was not unlike the modern synchronous converter, to the eye of the uninitiated, and it probably would have operated fairly satisfactorily under modern conditions of stable frequency, etc. However, this first machine was not built, due largely to the fact that it did not correspond to any commercial system of that time. In 1891 there were only two main frequencies in sight; namely, 133 cycles and 60 cycles; also there were no polyphase circuits available. Thus the synchronous converter at that time was the same kind of a waif as the polyphase induction motor, in that it had no polyphase system to which it could attach itself. Polyphase systems and lower frequencies were talked about, but, like the synchronous converter itself, were not yet in practical existence.

Sometime in 1891, the writer with several of his associates in the testing room of the Westinghouse Company, incidentally made a self-starting polyphase converter while doing some experimenting with a view to making a polyphase railway motor. It was desired to find what kind of starting conditions could be obtained on a railway motor with alternating current, instead of direct current. An experimental direct-current multipolar motor with slotted armature was equipped with a set of collector rings, in addition to its commutator, and was supplied with suitable polyphase current of low frequency. This machine was started and brought up to speed as an induction motor, in a series of tests, and, at synchronism, it delivered direct current from its commutator for self excitation, and to a lamp board, if the writers remember correctly. Anyhow, it was obvious from these tests that this machine could run synchronously and transform from alternating to direct current, which, however, was an expected result. This, therefore, constituted the first actual synchronous converter tested by the company with which the writer has been associated. While this test did not lead to anything in particular, yet it was convincing in showing that such conversion from alternating to direct current was practicable.

However, it was not until 1892 that deliberate efforts were made to transform, on a commercial scale, from alternating to direct current. It was becoming recognized that the polyphase system offered great future possibilities, and the synchronous converter began to be looked upon as one of the accessories of such a system. In consequence, arrangements were made to obtain tests on a relatively large scale to determine the possibilities of such a device. For this purpose, a standard 150-h.p., 500-volt, 850-revolution, four-pole belted type railway generator was equipped with four collector rings placed over one end of its commutator. Suitable brush holders were arranged for operating on these collector rings, in addition to the usual d-c. brush holder equipment. This machine was set up in the testing room and was started by means of a small direct current machine belted to it. It was synchronized with a low-frequency supply alternator, in the usual manner, by means of lamps.

From the first, this machine operated in a very satisfactory manner as a synchronous converter and a long series of tests were carried on by the writer, assisted Mr. N. W. Storer, at that time one of his associates in the testing room. It was determined that this machine would commutate in just as satisfactory a manner as when acting as a d-c. generator. As far as could be observed, the machine in every way was a practical one.

Meanwhile the whole synchronous converter situation was being worked over and it was decided that 3600 alternations (30 cycles) was about the best frequency for such machines. This was slightly higher than the frequency at which the tests were being made, but it was felt that this increase in frequency was permissible, in view of the excellent results already obtained at 3400 alternations (850 rev. per min., four poles). In those days everything was measured in alternations per minute, instead of cycles per second as in present practise.

About this time a Commission, which had taken up the development of the Niagara Falls power, had begun negotiations with the Westinghouse Company, with a view to getting certain electrical machinery constructed according to the designs of the Commission. The principal apparatus involved was an electric generator of 5000-h.p. capacity at 250 rev. per min. The design contemplated was the "umbrella type" with external rotating field and vertical shaft. This construction as a whole was considered practicable by the Westinghouse engineers, but the electrical proportions of these generators were not acceptable. The Commission had decided upon a frequency of 2000 alternations per minute (eight poles and 250 rev. per min., now $16\frac{2}{3}$ cycles per second). One of the objects in this low frequency was to be able to operate commutator-type motors by means of alternating current, as certain members of the Commission believed that this was the

solution of the small alternating current motor problem.

The Westinghouse Company objected to this low frequency and proposed, as an alternative, 16 poles at 250 revolutions, giving 4000 alternations per minute, or $33\frac{1}{3}$ cycles, this being the nearest that could be obtained to its own proposed standard of 30 cycles. There was very considerable discussion on the merits and demerits of these two frequencies. One of the advantages claimed for the higher frequency was that it would be much more suitable for synchronous converters, as the possible combinations of poles and speed would be very much greater than for $16\frac{2}{3}$ cycles. In fact, the lower frequency was considered to be more or less prohibitive as regards small or moderate capacity synchronous converters and induction motors, as their speeds would be too low. It is interesting to find how thoroughly this problem was appreciated, even at that early date, when only one experimental converter had been placed on test.

A compromise was finally made on the question of frequency by selecting a 12-pole machine for the Niagara generator, thus giving 3000 alternations, or 25 cycles. This was the origin of 25 cycles as a standard. The decision was made largely on the basis of future possibilities in the way of synchronous converters and induction motors.

The members of the Niagara Commission were informed that we had been carrying on extended tests with a direct current machine, modified into a converter and they witnessed the machine under load. During the discussion of the converter, the question came up as to whether such a machine had greater or less armature copper losses than a corresponding d-c. machine. Prof. Rowland, of the Commission, stated that he believed it to be the sum of the losses due to the alternating and direct currents in the windings, upon which Prof. Geo. Forbes, of the Commission, claimed that it represented the difference, these two eminent engineers taking opposite sides in all discussions. There was considerable argument, pro and con, with no prospects of a solution, as each of the contenders was depending purely upon argument. While such great authorities were discussing the matter, the writer thought it better not to venture an opinion, but he decided to make an actual test to settle the matter; so the following night he had the machine put on test as a converter to determine the comparative ratings, as a converter and as a d-c. generator. It so happened that in this machine there was a very definite load limit as a d-c. generator, for it had been proved by many tests that with a certain definite current for about four hours, it would begin to smoke. Consequently, tests were run to find the corresponding "smoking current" as a converter. The tests showed that with 400 amperes load, about the same heating (and smoking) conditions were produced in the armature copper as obtained with 280 amperes as a d-c. generator. This was a quite definite result, for it was known positively that this machine could not possibly carry 400 amperes for any appreciable length of time as a straight d-c. generator. Therefore, unquestionably, the armature loss was less as a converter than as a d-c. generator. When this result was placed before the electrical engineering members of the Commission, it apparently had no effect, as one of the members rejected the results and the other accepted them. However, the writer was thoroughly convinced, and so were all of his immediate associates. This, he believes, was the first actual test which indicated the relative capacities of the machine as a converter and as a d-c. generator.

To verify this test by calculation, both the writer and Mr. R. D. Mershon undertook to analyze the losses in the armature copper when acting as a converter. Mr. Mershon attempted a complete mathematical solution of the problem, whereas the writer undertook a simpler, less complete, but much quicker method by plotting out the calculated losses for each five electrical degrees of rotation of the armature windings. Curves were then plotted and the losses during a complete cycle of operation were summed up. This was worked out over-night so that the calculated results were available the next day. These showed 38 per cent loss as a two-phase machine and 57 per cent loss as a three-phase machine. This general result checked reasonably close to the actual test of the machine, considering that there were other losses involved in the problem. Mr. Mershon succeeded in his general mathematical analysis after about a week's effort and when he compared his results with those of the writer, they were found to coincide almost exactly. Thus the writer believes that he was the first to work out the problem of the relative losses, while Mr. Mershon was the first to make a complete mathematical analysis; and his mathematical results were published sometime later, but due to the newness of the subject, apparently little attention was paid it. Others published solutions much later, for which they received very considerable credit.

In addition to the above, some interesting experiments were carried on with this first experimental converter, especially in regard to methods of starting. Among other tests, the writer brought this machine up to speed as an a-c. single phase motor. By using the d-c. series winding as an a-c. field winding, connected in series with the armature to form an a-c. series motor, he actually started the machine from rest, brought it up to speed and then threw over to synchronism. This forms, therefore, a very early test of a large capacity series-wound single-phase commutator type motor.

These early synchronous converter tests were so successful and made the problem look so simple that apparently there was going to be no difficulty in developing a commercial line of converters, provided suitable low-frequency polyphase circuits were available. However, the real difficulties in synchronous converter operation did not develop until a considerable time later.

Based upon the aforesaid successful results, the West-

inghouse Company prepared a relatively large synchronous converter exhibit for the Chicago World's Fair in 1893. Some description should be made of this exhibit, as it was the first public exhibition of this type of apparatus, as far as the writer knows, where such machines were shown in actual operation.

In the latter part of 1892 the Westinghouse Company authorized the preparation of a polyphase exhibit for the Electricity Building at the World's Fair. This exhibit comprised a 250-h.p., two-phase, 60-cycle induction motor belted to a 500-h.p., two-phase, 30-cycle a-c-d-c. generator. From the d-c. side of this generator 500-volt direct current was to be furnished for operating any 500-volt direct-current apparatus in the exhibit, while from the a-c. side of the generator, a 30-cycle, two-phase current was to be supplied to two synchronous converters, one of 500 h.p. and the other of 60 h.p.

In view of the fact that no polyphase induction motor of such large horse power had ever been shown before and that the a-c-d-c. generator and the synchronous converters were both novel, this exhibit, taken as a whole, was a great novelty.

In looking over the original design specifications for the a-c-d-c. generator and the synchronous converter, dated Dec. 12, 1892, the writer finds some very interesting matter, from a historical standpoint. The specification for the 500-h.p. converter calls for a six-pole, 600-revolutions (30-cycle) 525-volt machine very much along modern lines of design. The pole pieces were laminated, but cast into the yoke, instead of bolted in. The armature was of the slotted type and with a "parallel type" winding, as in modern practise. This early specification calls for a brush lifting device for the d-c. brushes, although as actually built, the machine did not use such a device. However, it indicates that the possibility of brush trouble with a-c. starting was recognized. This converter was arranged to be started from low-voltage taps on an auto-transformer, and it was intended that the machine should come up to synchronous speed on the lowest tap and then be transferred to full voltage by successive steps. This was actually carried out and the converter was started and synchronized in this manner. The original specification also called for series field coils, for compounding but these were not incorporated in the actual machine. A further feature was that this converter was provided with a relatively small airgap and very light shunt field coils, compared with d-c. machines of corresponding dimensions, as built at that time. Thus this converter, *as specified*, was more nearly of the modern type than the designs which followed it during the next four or five years. Another interesting feature was that the field coils in starting were switched from series to three parallels and closed through a starting resistance, thus anticipating practise of several years later.

The small converter, of 60 h.p. had cast iron poles and yoke and operated at 900 rev. per min. This was also arranged to be started by auto-transformers and with high resistance in the field.

The a-c.-d-c. generator was similar to the above described synchronous converter, except that it had a large airgap with relatively heavy field coils and was separately excited from a 120-volt exciter, of which the field excitation was varied to control the main generator.

This exhibit was delayed considerably and was not ready for operation until about the first of July, 1893, although most of the apparatus was installed in May to serve for a stationary exhibit. On account of this delay, quite a number of other exhibitors thought that this exhibit, from the operating standpoint, was all a "bluff." However, operation was delayed until the writer visited the exhibit about the first of July. He then reviewed the entire layout of this exhibit and assisted in testing out some of the individual parts. Then one Sunday afternoon when there were no visitors around, but only exhibitors and attendants fixing up their exhibits, the 250-h.p. induction motor was started up, bringing the a-c.-d-c. generator up to speed. The large synchronous converter was then thrown on and brought up to speed, also the small converter and various special apparatus, which was to be operated by current from these two converters, was set in motion, so that the entire stationary exhibit became very much alive in a few minutes time. It was interesting to see the various attendants and exhibitors in the neighboring spaces stretching their necks to see what was going on. With everything in operation, it made considerable noise, especially noticeable with everything else in the building at a standstill. People flocked from all directions to see what was happening. An engineer from a neighboring German exhibit came over and shook hands with the writer and admitted that he was mistaken about the Westinghouse company, as he had thought that the whole exhibit was never intended to be run.

When this exhibit was first operated, several unusual things occurred which were not anticipated. One of these was a peculiar "beating" sound which occurred at times in the 60-h.p., 50-volt converter. Under certain conditions of voltage and field strength, it made this peculiar noise and sparked to a certain extent, even when carrying no load. However, under normal operating conditions, there was no such apparent trouble and no further investigations were made. This was probably the first observed case of "hunting" in a synchronous converter, but it was not serious enough to lead anyone to suspect an inherent difficulty. Another thing that developed in starting this exhibit was the relatively large input required to start the synchronous converter and bring it up to synchronism. Apparently this had considerable to do with the later practise of using starting motors to bring the converters up to speed. Starting the 500 h. p. converter from rest and bringing it up to synchronism proved to be about all that the 500-h.p., a-c.-d-c. generator could handle

and the effects on the other service operated from the a-c. side of the generator were rather appalling when the large converter was started.

All of the above refers to Westinghouse apparatus at the Chicago Exposition. The General Electric Co. had one relatively small capacity synchronous converter on exhibition, which the writer examined. This appeared to be a very nicely constructed machine, but as there was no suitable supply circuit the machine was therefore not operated. For this reason apparently, it attracted but little attention, as the electrical public at that time had heard practically nothing about synchronous converters.

25-Cycle Converters

As far as the writer's knowledge goes, the next step in the synchronous converter development was in connection with a couple of 200-kw., 25-cycle converters to be used as exciters for the Niagara Falls Power Company's 25-cycle generating plant. These machines were built in 1894 and were very much along the lines of the World's Fair 500-h.p. converter, having laminated poles, and with no dampers, the need for the latter not having developed. One of these machines was operated from one of the Niagara generators in the Westinghouse shops and apparently ran all right except on one occasion when there was a violent "pumping" or "beating" sound in the converter and it sparked very badly, so much so that it was cut off the circuit. When put on again, it ran satisfactorily and it was assumed that some mistake had been made which caused the preceding trouble. This was not recognized as a case of hunting, neither was any connection noted between this trouble and the few instances of hunting in the small machine at the World's Fair exhibit. In fact, here were two cases of hunting on record which, however, did not attract any particular attention. It was only after the converters were installed at Niagara Falls that the true seriousness of the difficulty developed. It was then found that these machines would not work at all as synchronous converters, due to apparent irregular rotation accompanied by the violent sparking, etc., noted in one of the shop tests.

Meanwhile the General Electric Co. had been following up the synchronous converter situation and was building such machines for some of the Edison companies to be operated on 25-cycle engine-type generators. A number of these machines were installed and appeared to work in a quite satisfactory manner. In parallel with such development, the Westinghouse company was also building 25-cycle converters under contract with a number of customers, apparently unaware that they were facing a very difficult situation. Outside of the two converters built for exciters, as mentioned above, the first serious trouble encountered was in connection with a couple of chemical plants at Niagara Falls. Several converters had been contracted for by two such plants and also the World's Fair 500-h.p. converter, already described, had been reconstructed into a 500-kw., 550-volt machine, which was set up in the main power house at Niagara Falls. This latter machine appeared to operate in a quite satisfactory manner, and we thus gained undue confidence. The General Electric Co. had quite a large contract for synchronous converters for the Pittsburgh Aluminum Company's Plant at Niagara Falls. Apparently it approached this matter with full confidence also.

The Westinghouse converters in the chemical plants at Niagara Falls were built along well known lines, having slotted armature, laminated poles, etc. The General Electric machines for the Aluminum company were somewhat more radical in type, having surface wound armatures and metal brushes on the commutators. The machines of both manufacturers soon got into serious trouble, although from quite different causes. The Westinghouse machines were troubled almost at once with hunting, as we now call it. In both plants, known as the Niagara Electric Chemical Co. and the Chemical Construction Co., the converters refused to operate without very bad hunting at times. It was then appreciated that the trouble indications in the shop tests, and in the Chicago exhibit, really meant something. The writer and Mr. C. F. Scott spent a long period working on these converters to stop the hunting, and all kinds of "stunts" were tried, one of which was short circuiting part of the field coils. It had been noted that the exciting current varied as the machine hunted and therefore it was assumed that a heavy short circuited path around the field poles might exert a steadying effect. This idea proved to be correct, but this damping was not sufficient to stop the hunting. However, in the course of these tests, the entire field circuit was disconnected from the commutator and closed on itself, on one of the machines, and it continued in synchronism and carried load as a converter through armature excitation alone, and what is more, there was absolutely no hunting under this condition. This was tried on the machines in both the chemical plants and was effective in both cases. An objection, however, was that the power factor of the a-c. input was quite bad, due to the large magnetizing current. Various tests were made to determine what was going on during this hunting and it developed that the armature of the converter was acting alternately as a generator and as a motor, and the armature magnetomotive force was reversing with each "beat." It appeared also, that the machine was alternately gaining and losing speed in respect to the supply system, during the beats. In other words, the armature was running at an oscillating speed.

While these tests showed pretty clearly what was happening, the proper remedy did not suggest itself until sometime afterwards. One thing was evident; namely, none of the converters would "hunt" when running without field excitation. Therefore, it at once suggested itself that if the airgaps were made very

small, that is, comparable with those of induction motors, then the converters might be made to operate without hunting and with magnetizing currents and power factors comparable with good induction motors. As this was the only feasible solution in sight, plans were immediately made to furnish new magnetic fields for one of the Electro-Chemical company's machines, in which an extremely small airgap would be used. This was done as quickly as possible and on trial this machine appeared to give quite satisfactory operation. Further tests indicated that the hunting problem in general was so serious that we might be obliged to go to this "induction converter" eventually for all synchronous converter work.

However, while this was being done, a further analysis was being made of the general problem. The writer, with one of his associates, undertook to explore the magnetic field conditions in one of the Niagara converters during hunting to see what was actually occurring. A wooden arm was fixed over the commutator with a large number of uniformly spaced holes in it, through which metal contacts were pushed to the commutator surface. Voltmeter readings were taken for each position, over a wide arc of the commutator. It was found that the voltage readings were varying, with the beats in the machine, from a high value in one beat to a low value in the next. Plotting out these two extremes, two curves were obtained, as indicated in Fig. 1. Each of these represents the field flux distribution or "field form" under one of the extremes in the hunting action. Superposing these, as in Fig. 1, it was obvious that the magnetic field was being alternately distorted in one direction and then the reverse, just as if the armature magnetomotive force were reversing. This set of curves explained many things. It was the study of these that soon led to the correct solution of the hunting problem. The writer attempted to do some figuring on the armature magnetomotive forces required to produce the distortions shown in Fig. 1, and while doing this, it occurred to him that as the larger

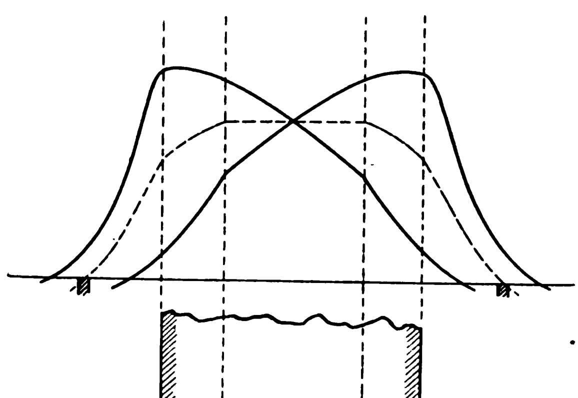


Fig. 1

part of the flux changes were at the edges of the poles, and as the poles had a very considerable "bevel," it might be possible to put a heavy copper plate under each pole edge, which would act as a secondary or "damper" to lessen or minimize the flux changes. At the same time it was recognized that a closed circuit around the field pole itself had a steadying action, as indicated by the tests. In consequence, the writer then proposed that a heavy copper plate or damper, such as shown in Fig. 1, be placed on the pole tips of a converter to see whether it would affect the hunting. In the latter part of 1896 a damper of this type was fitted on one of the Niagara exciters, which, as said before, were utterly inoperative when installed in the Niagara plant. Immediately after this modification, this exciter operated with entire satisfaction as a converter and all hunting disappeared. Obviously, therefore, this was a revolutionary improvement. Immediately plans were made to install such dampers on other machines already built or building, and in each case hunting was overcome. This therefore, was the origin in this country of the damper on synchronous converters, although the later types have departed considerably from this early form.

Meanwhile, however, various other devices to lessen hunting were being tried by other people, as well as the Westinghouse engineers. Among these was the use of a heavy flywheel on the converter, both of flexibly and non-flexibly driven types. The non-flexibly driven flywheel apparently was not entirely effective. The flexibly driven flywheel was to a certain extent effective, according to statements at that time, although the writer had no personal experience with this construction.

Meanwhile, the General Electric Co. seemed to be getting along in a fairly satisfactory manner without any dampers, but the real reason for its better success was apparently not fully appreciated at the time. Its 25-cycle converters at that time were built with solid steel poles, like its d-c. generators, and it was not recognized at first that these in themselves furnished enough damping capacity for most of the 25-cycle machines. In fact, in discussing synchronous converters at a meeting at Niagara Falls in 1897 the Westinghouse engineers took the position that hunting was due, partly, to discrepancies in wave form between the converter and the generator, whereas the General Electric engineers contended that it was due, partly, to the use of two-phase converters, instead of three-phase, as they had no hunting with their three-phase machines. Both of these claims had to be discarded, on later evidence. Recalling this discussion some years later in a reminiscent conversation, Dr. Steinmetz told the writer how his associates and himself had "fooled" themselves into thinking that three-phase converters would not hunt and then, all at once, they discovered, when they used laminated poles, that the three-phase machines would hunt just as badly as the two-phase.

[*Continued on page 59.*]

Economical Power: The Strongest Agent for Maintaining Supremacy in World's Trade

BY W. S. MURRAY
Consulting Engineer, New York

I AM not fearful of being misunderstood when I say: "Proud as I am of my country, I challenge the denial that we have been a profligate and wasteful nation in the extreme. Drunk with the wealth of our natural resources we have eschewed their conservation and rolled in a criminal debauch of their treasure." These are strong words, but I deliver them to strong men.

The remarks I have made are a fair foundation upon which to stand in bringing to your consideration the application of these principles to a specific plan which has for its central idea the saving to the nation of $300,000,000 annually, the construction of a regional plant to supply the power demand in a territory that may well be described as the finishing shop of American industry and a release to the railroads from the hauling of 50 per cent of the coal now transported, which amount, by virtue of improper power generation and distribution, is literally thrown away!

A few years ago in Logan County, West Virginia, scattered about on its mining properties there was installed a total of 4000 h.p. in boilers to supply the power requirements. Go there today and you will see one central electric station supplying the same demand with a boiler capacity of 500 h.p. Electric wires have been substituted for the steam mains. So great was the diversity factor of power required at the mines that the single central station is capable of furnishing with 500 h.p. what it took 4000 h.p. to accomplish with the scattered plants. A ratio of 1 to 8, and why? Because the central station generated its power at maximum efficiency and furnished all the power required from one transmission bus. Three mines might each have required 200 h.p. but their demand did not come at the same time. I cite this case as it is, in a way, comparable with the situation that now exists in a territory between Boston and Washington and inland from the coast averaging 100 miles. In this belt, to satisfy the industrial demand there is an installed machine capacity of 10,000,000 horse power. Two-thirds of this demand is for industries, such as: Iron and steel, foundry and machine, textile, lumber, pulp and paper, flour and grist, car shops, rubber, automobiles. The horse power in steam locomotives totals 7,000,000 and the combination of these two great classifications of power requirement offers unexampled opportunity in the application of diversity factor; that is power delivered from the same source to different points at different times.

It has been said that the electrification of the New Haven road was a well conceived and well executed engineering project. As the electrical engineer in charge of this work, some credit has been transferred to my shoulders, and in using the word transferred I do so advisedly, for doubtless much credit was transferred that did not belong to me. That the system has been accepted by the Swiss people as standard for its government roads, and that the Pennsylvania road has installed it on its main line between New York and Philadelphia, is assurance enough that the initiative of the New Haven engineers was based on sound reasoning.

The great lesson the New Haven electrification taught me was not how the catenary wires should be strung over the propulsion rails, but what the economic results are, now that the catenary wires are there.

My message to you today is that we save this $300,000,000 yearly loss, and it can be done by means absolutely within our power, if we but demand that it be done. I do not so construct that sentence to indicate that there is a single person, company or corporation who would stand in the way of such a procedure. Indeed the plan which I shall unfold to you has the hearty endorsement of the engineering and technical press and such societies as the Boston branch of the A. I. E. E., the National Electrical Light Association and now Engineering Council.

I have such enthusiastic support from those so well qualified to pass upon the matter that it is with these encouragements I am brought to you today to promulgate ways and means of bringing the matter to a definite focus looking toward congressional approval and procedure.

The New Haven electrification has shown beyond peradventure of doubt that its passenger, freight and switching wheels can be turned by electricity for less than half the amount of coal expended for steam locomotive operation, and this result is obtained using a source of electrical power, the operating efficiency of which is only one-half that contemplated in the plan to be proposed. The cost of maintenance of steam locomotives is conservatively double that of electric locomotives ton for ton on drivers. These are the two great economies to be secured in the electrification of heavy traction roads. A third economy is that secured in the ability of the electric locomotives to develop greater tractive efforts and speeds than the steam

**Address before the Connecticut Chamber of Commerce, November 19, 1919.*

locomotives, and by so doing consolidate trains with consequent reduction of train-miles, which is an item of great economic value under operating expense.

What has been said about the railroads can be said with even more telling effect about the industrial plants. From the figures preceding it is clear that there is a clean-cut coal saving of four to one if the railroads are operated by electricity. The saving as between electric and steam drive in factories is as high as ten to one; and again there appears, as in the case of the railroads, the greatly reduced cost of maintaining electric versus steam equipment in the factories.

The present load factor of this great regional demand for power is not more than 15 per cent. This means that for every 15 h.p. required, 100 h.p. is installed; whereas in the plan to be proposed the load factor can be increased to 50 per cent or more. Load factor is the ratio of the average load to the maximum. Today, due to the improper form of power generation and distribution, for every ton of coal burned another is wasted—literally thrown away.

By the construction of high-powered, high-economy tidewater steam and hydroelectric stations and steam stations erected at the mouths of mines, within the territory named, all interconnected with a super-power transmission system, using also the large plants now in existence in the larger cities such as Boston, Providence, New York, Philadelphia and Baltimore, there will be integrated one great regional zone, inherent to which will be the three great adjuncts of economical power production, *viz:* High load factor, low coal consumption and continuity of power production (due to an established breakdown service between power centers).

In this presentation it should be borne in mind that between Washington and Boston the contribution of water powers to the regional plant will be but a small percentage of the whole; steam plants at tide water and at the mouths of mines carrying the load up to 90 per cent of the total developed power. However, as the super-power line later is extended, north from Boston and south from Washington, these extensions will reach into the Northern and Southern water power districts and the percentage of water power generated will be increased.

Forgetting now for the moment the yearly savings of $300,000,000 to be secured by the above means let us view the matter from a transportation standpoint. Already the West is reaping its wonderful economic benefits from its developed water powers, while we in the East have but to look out of the windows of our train to see our sidings, our yards and even our main lines clogged with coal cars. Strings of empties and loaded coal cars are actually claiming 40 per cent of the cargo space devoted to transportation. The railroads are burdened with it and would hail a release. This is exactly what the Super-power system would give, for by its installation there would be created what might be termed a "common carrier for power." The railroads in the zone contemplated would be relieved of the necessity of hauling its 4 to 1 inefficient power on its own rails and those roads hauling coal to the proposed electrified zone would enjoy also, pro rata, the automatically created space, for new and higher priced commodities.

Preferred routes from the mines to the sea would be established for coal-bearing roads, and ocean tugs and barges would thus take the place of locomotives and cars for the supply of coal to the central electric station located on tide water. Can it not be well said since we refine oil and ore that we should refine coal? Power is minimum in bulk and maximum in efficiency of use when it is in the form of electricity.

Power is essential to railroads and industries. Without it all wheels must cease to turn. We have 75 years of anthracite coal left to us even if we do not increase the rate at which it is being mined today. We have leaped from 100,000,000 tons of bituminous coal per annum in the last twenty years to nearly 600,000,000 tons, and our Ohio, Illinois, Pennsylvania and Virginia fields are being rapidly exhausted. Cost, due to future location and increased transportation, is on the upgrade and there is no summit to the grade.

Our merchant marine is now building to carry the products of our industrialism, an expansion of which for this country is imminent. If we are to maintain a high standard of American wage and living and our supremacy in the world's trade, its guarantor must be economical power; I mean cheap and reliable power.

The thought which I am anxious to leave with you is that anyone who associates with this project the idea that it has even the lightest shade of local color is wrong. The real thought being that it is one of broad, National scope.

The West is indeed fortunate in the present development and opportunity of further development of her great water powers, and is thus not dependent upon fuel as a base for power production, while we in the East, mindful indeed of the few accessible water powers which will be unquestionably developed, know they represent less than 10 per cent of the total power requirement.

Further, here in the East, due to the present improper form of power generation and distribution, our railroads are congested with coal, only to be wasted and thus be non-productive of power. Is it not therefore a fair cry to ask National legislation which will bring about a high efficiency of power production and permit the coal now wasted in the East to flow to the Middle West for its needs, and by such a distribution make an equitable adjustment in the matter of power production over the whole country?

Many with whom I have discussed the super-power plan have inquired into the matter of what would be the status of the present companies dispensing electrical power, and have followed up their inquiry with regard to the method which would be pursued in financing the

Super-power system. These, of course, are two very important questions. In the case of the first, the answer is that the present companies would maintain their present entities, carrying all their present franchise rights. Their legal status, so far as I am able to see, would not in any way be modified. Indeed, they would more surely become what they would like to be, namely, distributors of power. The districts in which they operate would receive power in bulk from the Super-power system either or both at the points of their present central stations, and substations to be erected —the latter location being in conformity with the highest degree of economic distribution.

As in the case of the local distributing companies, the Super-power system would be entirely individual to itself, and so financed; its object being the generation and transmission of power to the distributing companies with the sole object of getting that power to them at the lowest cost of production consistent with the highest degree of continuity of service.

By far the most important immediate consideration is the investigation Secretary Lane has proposed to Congress by which will be determined the amount and location of waste in this Northeast Atlantic Seaboard Zone, and in the report to be written under the auspices of the Department of the Interior there will be developed engineering and construction plans necessary to its saving.

Now, with regard to the second question, that of financing, a regional plant of the character I have described, it will require the expenditure of a very large sum of money, which however simply points to a truth, the knowledge of which is yours, that we are not only upon the eve, but in the realm of far larger things than have concerned us in the past. Yesterday we were willing to spend a million dollars in construction to save one hundred thousand a year. Today we are ready to spend a billion to save a hundred million a year.

It is my belief that if by this investigation it is proved that in the zone above described there is going to waste $300,000,000 a year, and a perfectly practicable plan is ready at our hands, by which its saving can be effected, there will be no question as to whether it can be financed, but rather what will be the best method of finance to pursue.

What I have had to say should not be construed as any criticism of present central station practise. The people of this country are deeply beholden to those interests who, through their central stations, produce and distribute power so economically. Every time I see white steam rising from the exhaust of some small isolated plant I know that that plant is contributing to the waste we are discussing, and would be reduced if power were delivered to that plant direct from the lines of a large central station. Too often indeed have politics entered into the decision of public commissioners, whereby the central stations' interests have been unwarrantedly attacked and grievously hurt. The introduction of the Super-power system is but to carry on to higher efficiency the work so splendidly begun by the central stations. In a word, it is the great untouched regions in which power is *produced wastefully* which now offer themselves as a market to the Super-power system; the new stations to be built combining with the existing larger plants to furnish that power.

This is, you may say, such a tremendous thing. How will we ever be able to accomplish it? It rather takes your breath away and yet, gentlemen, it is as simple as it is large. There is not one detail in its assembly that has not been thoroughly tried out from an engineering, construction and operating standpoint. We have all the materials, we have the location, we have every room rented in advance—it is time to construct the building! We can liken it to the machine shop starting with its little 20 h.p. engine and boiler. Trade prospers and an extension to the building is made with another engine and boiler and again another extension, but all the while the increments are of the order of the first plant, carrying with them their inefficiencies in power and method of the early years. Then suddenly the owners realize that their business and power requirements are sufficiently large to wipe out seven-eighths of their original plant and build a new shop, employing the principles governing the new one-eighth. The case cited, small and insignificant as it is, is a perfect simile to the Super-power system. Throughout the zone I have described there is a demand for one-third of the total industrial horse power produced in the country, and but a small per cent of our railroad tonnage is moved by this highly efficient power agent, electricity, and so as the increments of power have been added in this territory to meet the ever growing demand, and now greatly enhanced by this burst of industrial expansion, in turn requiring increased railway facility, we find ourselves with a plant of scattered boilers, as in the case of the Logan County, W.Va. mining district, only five thousand fold magnified. The greatest assembled load of the world has grown up under this inefficient supply! It is ready now to be transferred to the busses of a regional system whose guarantee will be continuity of service and a saving to the people of $300,000,000 a year. In that presentation I ask you if the case, large as it may seem, is not a simple one.

The United States Geological Survey, Department of the Interior, the office of which is administered by Dr. George Otis Smith, presents under October 29, 1919, some very interesting statistics concerning the division of power resources of this country, and which concerns the relative production of electric energy by water versus fuel.

Taking the month of March, which is one of the maximum months of water power production, the combined water power output of central stations supplying power for public utilities in the following states:

Rhode Island, Connecticut, New Jersey, Pennsylvania, Delaware and Maryland was approximately 119,500,000 kw-hr., while the energy produced by fuel was 498,000,000 kw-hr. This means, therefore, that water produced less than 20 per cent of the total energy.

I have purposely eliminated the State of New York, as the water power production for that state is confined chiefly to the section of the country immediately adjacent to Niagara Falls. Should this state be included, the ratio rises to 30 per cent but even with Niagara Falls included it is to be noted that the water power production is less than a third.

Taking a dry month, and again excluding New York State, the ratio of water power production sinks to less than 10 per cent, and if all the industrial and railroad wheels in the zone contemplated were turned by electricity the *average* water power available would be considerably less than 10 per cent of the whole. It is interesting, too, at this juncture to say that while nearly *100 per cent* of the load in this zone could be handled by electricity, we find today that less than *33 per cent* of it is being so handled.

I am sure you will be amazed to know that in the New England States, and New York, Pennsylvania and New Jersey alone, there is shipped into this territory 37,000 tons of coal daily for public utility central stations.

The total coal tonnage used by all the electric power plants in this country, engaged in public service, is only 95,000 tons per day, and thus in only a part of the zone we are discussing, representing less than 5 per cent of the total area of the United States, there is required 40 per cent of the total amount of coal so used.

Again, another point of view: To ship this amount of coal into this district requires over 800 cars in and out every day. This would represent a solid train of coal cars seven miles long. Now you have but to visualize this train split up into units, varying say from one car to ten, being switched in the yards, on the sidings and many times on the main lines. Does not an arrangement so inefficient, so clumsy and so costly fairly make one cry out in despair for a unified common carrier system of power, especially when it is known that every day but adds to this confusing congestion?

All this points to the inevitable conclusion that the power for this great finishing shop of American industry must in a large measure be furnished with fuel as a base. Are we willing wantonly to blast the hopes of posterity? Is not our duty plainly in sight? Must we not perform? Therefore, I say to you, we must look to remedial methods of power production, which we have at our fingers' ends, to prevent this impending catastrophe.

Please do not conclude from what I have said that we should not develop every waterfall economically within the radius of this Eastern district, and this includes powers which exist on such rivers as the Connecticut, Housatonic, Susquehanna, Delaware and Potomac, and many others between them, of which doubtless their names are unknown to you. As an example of the latter class while acting as Chairman of a committee of engineers during the war, a report to the Government was made on one—the Wallenpaupuck flowing through Pike County, Pennsylvania. Its economy as compared to a steam station of equal capacity, was such that the steam station would have had to be amortized (on an 8 per cent basis) to the extent of $12,000,000, (which, too, happened to be the cost of the hydroelectric station) before it began to compete with the water plant!

Gentlemen, there is no danger or chance of failure in this regional plant to perform. Every engineer in the country whose experience has been of the order of mine, knows where the danger lies; that it is in this drift, drift, drift policy, an attitude of "letting well enough alone" when the "well enough" is in fact a willingness to let this American birthright to supremacy in world's trade be taken away from us and from beneath our very noses; and I say to you New England men, among whom I have lived in affectionate regard, that you are practicing a conservatism locked in the arms of failure.

In the vernacular of the American youth, "You are asleep at the switch." The world has caught up with you, and is passing you. You fought for what you got; now you have got to fight to hold on to it, and you have got to start the fight not tomorrow, but today. One of New England's solid men said to me the other day, apropos of the New England situation and its fine practise of conservatism; "Economical power is the sole remaining means to prevent this finishing shop of American industry from being converted into the playground of American tourists." These, gentlemen, as you know only too well, are not idle words. One has but to read the signs and then predict the result. Power is being produced nearly everywhere more cheaply than in this zone. Yet this zone is the American home of skilled labor. That labor does not wish to migrate, but it will migrate unless you make economical power migrate to it, and the distance it will have to go will not be far with the means now at hand to eliminate this criminal waste.

I feel sure you realize now the immeasurable waste of human and national treasure that is going, on, yet a few among the many will say: Why the cost of power does not represent 5 per cent of my manufacturing cost! The perspective of a man who says that ends one inch from the end of his nose, and he admits in the same breath that the conservation of the Nation's resources is nothing to him. He also puts himself at once in a losing class. Why? Because while electricity *is* the agent of highest efficiency in power application, yet as such it is *nothing* compared to its efficiency as an agent to facility. What this country has got to do to maintain her supremacy in world's trade is to produce, produce, and then produce more. Even if the cost of electricity's application were twice as much as steam

its contribution to the facility of production, in nearly every form, would far outweigh the additional cost. A hundred examples spring to one's lips: In the factory—the individual machine driven tools; on the railroads—the multiple-unit locomotives operated from either end. (The turn table and ash pit are things of the past for the 100 per cent operated electric division).

I saw a sign the other day on the walls of a central power station, it said: "Electricity for Everything." The average manufacturer worries himself to death about his coal pile. Visualize the miserable little coal piles scattered all over this great industrial region. What do they stand for? Congested traffic, throttled production and waste of our national resources. If we practise what was said on that sign what will that stand for? Open traffic, greater production and conservation.

Before closing there are two other aspects I would touch upon under a slogan I offer now for your consideration.

We have spent billions for destruction for preservation now let us spend billions for construction for conservation.

The first: We are the greatest industrial nation of the world. How can we better maintain that supremacy than by giving employment to the millions of our boys that have crossed the sea to maintain the principles for which this nation stood. This plan offers employment in factory and field, and when completed will be the kenetic embodiment of national wealth—a living, active, producing tool, guarding national conservation. *The World's Work* for November, 1919, page 14 (as reading from Mr. Hoover's analysis on page 98) says:

The present high prices both here and abroad are the result of a lack of useful products. During the war economically useless products were produced under great pressure at high costs. The high cost of production still continues and applies to all products. Our old ability to produce cheaply by means of machinery and to pay the producer a wage with which he can keep up a relatively high standard of living is in danger. The wage is high but the purchasing power of it is not. The only solution is to give the producer better tools, better machinery, better management, so that he can increase his product and get more money for it to meet the high prices, and to have the worker give more brains and energy to match this improvement.

The second, Mr. Frederick Darlington, whose excellent work on the War Industries Board is well known, says:

In the central power station business so much of the cost of service goes to pay for invested capital that it is most essential that the interest rates should be kept low which can be done only by making the investment safe, that is; by so regulating rates that principal and interest will be secured. From a national point of view, as effecting the general industrial efficiency of our manufacturing and power-consuming districts, it is relatively unimportant whether the cost of power is one mill or two mills per unit more or less than some established rate, whereas it is of vital importance for the conservation of resources, for economy of production and for general industrial efficiency that the bulk of the power used should be made by central systems as against isolated plants; therefore let us try to get our law-makers and public executives, national, state and municipal, to take the Government point of view, in other words, to think in terms of the war which are also terms of peace from a Government standpoint, and to uniformly and rationally encourage central power development, provide for a just return to capital in electric power business and grant monopolies under regulations that will foster co-ordination and interstate operations.

Especially also would I draw your attention to the proceedings of the National Electric Light Association covering its recent deliberations at the Atlantic City Convention in which will be found the address of Dr. George Otis Smith, Director of Geological Survey. Director Smith's address is a splendid endorsement of Secretary Lane's request for Congress to provide sufficient funds to the Department of the Interior by which an investigation can be made to allocate the losses now sustained and to be inclusive of recommendations covering a power transmission and distribution system by which they may be saved.

This appropriation will come under general expenses of the Geological Survey and be a part of the general civil sundry bill.

If what I have said has appeared to you as reasonable and constructive it would be a pleasure indeed to have your endorsement of it.

DISCUSSION BY E. G. BUCKLAND

President N. Y., N. H. & H. Railroad

In the winter of 1917–18 New England faced a serious coal shortage. There was much suffering, a partial paralysis of business and a threatened stoppage of transportation. We who were responsible for transportation facilities in New England did our best to continue the carriage of freight and passengers and to keep the industries running. We divided our coal piles with our less fortunate neighbors and in some instances our more fortunate neighbors divided their coal piles with us. It was a time when on the other side of the water the war was going against us and on this side it seemed as if nature had conspired to favor the enemy. Now, while this emergency brought out the finest qualities of generous cooperation between industries and carriers yet those who would continue to be responsible for transportation facilities felt that if it were possible a coal shortage in New England should never be permitted to occur again. Coal stands for energy however it may appear, and it is this shortage of power which has seasonally handicapped New England. It had occurred to some of us who have studied this situation that there were possibilities of power and coal conservation which had not yet been developed. I personally knew that Mr. William S.

Murray had given the matter a great deal of thought and after talking with him and likening the situation to the conservation of forests and the conservation of water power in the west, wrote to Hon. Franklin K. Lane, Secretary of the Interior, and asked him if it were not possible to include in his conservation projects one looking to the conservation of power in New England, pointing out to him the possibility of combining unused water power in New England, with power from tide water coal brought to New England ports and unmerchantable coal, developing power at the mines in the coal regions of Pennsylvania and the Virginias. Secretary Lane immediately answered that the subject was one to which he and Doctor George Otis Smith, Director, Geological Survey, had given much thought and that he had already asked for an appropriation to make a general survey of the country looking to the correlation and conservation of all sorts of power. Mr. Murray and I thereupon went to Washington, consulted with Secretary Lane and Dr. George Otis Smith and found that our ideas were at one, as a result of which Secretary Lane has brought the matter before Congress and is asking for authority to make a general survey of the United States and an extensive survey of what he calls the Boston-Washington district, with the idea of reporting the possibilities of marshalling the sources of power and conserving the coal supply.

It has been said that the man who makes two blades of grass to grow where one has grown before is a public benefactor. Obviously a man who in New England can make one pound of coal do what two pounds has done before is even a greater benefactor and even though coal be the largest single item of freight revenue no carrier having the good of the public at heart could afford to oppose a plan which cuts the cost of power in New England. For every dollar lost by diminishing the coal hauled there will be more than a dollar gained from the increased traffic on higher class products. New England has long been handicapped by its lack of coal and raw materials. It has a wonderful supply of pure water, a climate conducive to skilled labor, communities where skilled labor finds congenial homes and fine educational institutions for the upbringing of families, but unless it can hold its own in the prices of its products all of its advantages will be overbalanced by its burdens, and the greatest of its burdens is its lack of power supply.

Therefore, the question confronting railroads and industries in New England has ceased to be the usual issue between shipper and carrier but has become a question as to what the carrier can do for the shipper and what the shipper can do for the carrier in order to keep New England's industrial supremacy from leaving and New England from being turned into a rich man's playground. We believe that with New England's proximity to tide water, with its undeveloped water powers, and with the enormous economies to come from developing electrical current from large central stations and hydroelectric developments it can continue to compete in the markets of the United States as well as the markets of the world. It is to that end that this group should recommend that the Chamber of Commerce further the efforts now being made by the Secretary of the Interior to obtain an intelligent idea of the savings which will result from a survey of the sources of power between Boston and Washington with the idea of contributing them to a common channel and distributing to consumers within that region.

DISCUSSION BY CHAS. F. SCOTT

Professor of Electrical Engineering, Yale University

The statement has recently been made that the limit to industrial expansion is likely to be in transportation facilities, that is, in the ability to supply raw material and distribute products. The railroads have been hard pressed; war requirements exceeded their capability and the Government took over the railroads and employed the methods of unification and coordination which it had formerly prevented the railroads from adopting. The ton-miles of freight in the United States was more than three times as great in 1916 as it was in 1900. If industrial expansion is to continue, railroad facilities must be increased and the way to increase them in congested regions is by electrification. This not only increases the traffic capacity of tracks and terminals but it reduces the coal required for railroad operation. A general electrification of industry will further reduce the coal to be transported for industry thereby releasing the equipment for industrial freight.

Mr. Murray's paper may be reinforced in two points; first, as to the increased usefulness of electrical power in industry, and second, as to the future demands.

New England is a manufacturing community without raw materials or coal. Its asset is the skill of its people. The prime business is devising and operating machinery which uses power. Excellence and economy depend largely upon the kind of power available. Electric power repeatedly proves its superiority in industry for lighting, for motor application, for furnaces and ovens, by reducing costs, improving quality and increasing output. The two fundamental requisites of New England industry are electric power and transportation. The universal power system is the key to both.

Mr. Murray's statements of large savings refer to present conditions; they do not include future growth. Pre-war curves show a growth in industry in which the primary horse power in industries in the United States has increased from 10,000,000 in 1899 to 22,500,000 in 1914. In the same period the horse power in New England and the middle Atlantic States doubled. The proportion of this power applied electrically has increased in far greater ratio, doubling in about five year periods. This means, if the curves of recent progress are continued during the next decade, that in

ten years the total power will be on the order of double what it is now and that the electric power will increase four fold. This is a matter of enormous magnitude and of vital concern as a factor in production, which was never more greatly needed than now. The economies in the future should greatly exceed those which Mr. Murray estimates would be possible now. There is every reason why a broad gage general survey of the problem should be undertaken at once.

If the use of electric power continues to increase at its past rate and is double in five years from now, then the electric energy to be produced during the next five year period will aggregate a total number of kilowatt-hours equal to the total which have been produced in the past forty years. It is certainly worth while to determine what the demand probably will be and to plan the best way of supplying it.

DISCUSSION BY SAMUEL FERGUSON

Vice-President Hartford Electric Light Co.

I wish to emphasize one point touched on by Mr. Murray, namely, the need that the Connecticut representatives at Washington should be made to realize that we are interested in this plan and approve Secretary Lane's request for an appropriation of $200,000. for a survey and report; and I hope that the resolution committee will favorably report a resolution to that effect at the general meeting tomorrow. In addition, our congressmen should hear from individuals.

The outline as given by Mr. Murray is a wonderful conception, but probably its very vastness is discouraging to some on account of the legislation and financing, which apparently must first be done: To me, this is not so, because if every section of New England keeps this plan in mind as an ultimate solution, and if all central power companies and manufacturers make their investments for power production or power utilization, in such a manner that each will eventually become an integral part of the system, the final consolidation will become a relatively simple affair.

In answer to Mr. Wright's question as to what gain there could be to manufacturers in Hartford, I would simply state as one instance of gain, that at present about 13,000 h.p. of surplus station capacity is installed there and held idle from one years' end to the other, simply as a reserve in case of failure of other apparatus. If, then, the Hartford plant were connected to the super transmission system, this investment when not needed locally, could be used to furnish current to the system, thus earning its fixed charges, rather than as at present, having the fixed charges of the spare investment absorbed in the local price of power.

As an apt illustration, three hours ago a serious accident happened to the Waterbury power station. By quick work and emergency connection, the above mentioned reserve capacity is now being used to supply part of the Waterbury deficit. Under Mr. Murray's plan there would have been no interruption, as the inter-connection would have been such that a failure in one part would be automatically taken care of by the next section.

CANADA'S LARGE PROJECT

OPERATING the largest shovels in the world and reversing the flow of the Welland river, the Hydro-Electric Power Commission of Ontario is carrying on what is said to be the most extensive engineering project on the North American continent—and that practically without the use of steam.

To get water to the new power house to be built above Queenston, the Commission will utilize four and a quarter miles of the river. This will cause that stream to flow backward and take water from the Niagara river. The commission expects to have the new plant working by 1922. The project will cost around $27,000,000.

Two miles above the brink of Niagara Falls, a steam dredge is gnawing away at the channel of the Welland river. This dredge and the attendant tugs are the only equipment engaged on the improvement that are not owned by the Commission. They and seven switch engines are the only steam-propelled apparatus used on the development.

Drills boring through the rock of the canal right of way are operated by air, electrically compressed. Electrically-controlled clamshells swung from aerial cableways, huge electric shovels, electric trains and electrically operated rock crushers show how the Genie of Electricity has been made the slave of the engineer.—*Cleveland Engineering.*

GIFT OF A BUST OF FRANKLIN

A welcome addition to the artistic possessions of the headquarters of the Institute has been made by the gift of a tinted plaster bust of Benjamin Franklin, by past president T. C. Martin. The original of the bust in marble is in the collection of the Pennsylvania Academy of the Fine Arts, at Philadelphia. It was executed in 1777 by Jean Jacques Caffieri, sculptor to the King of France and professor in the Royal Academy of Painting and Sculpture; and for many years was attributed to Ceracchi, under circumstances which are very interestingly set forth in "Jean Antoine Houdon" by Charles Henry Hart and Edward Biddle, who describe in detail the various differences between the Caffieri bust and that by Houdon, to which they prefer it for technical and artistic reasons. Caffieri was also the sculptor of the tablet to the memory of Major General Richard Montgomery, in the portico of St. Paul's Church, New York City, in vari-colored marbles. This, the oldest monument on Manhattan Island, was erected some little time after the glorious death of Montgomery at the capture of Quebec. It is interesting to note that the records of the Pennsylvania Academy still attribute the bust to Ceracchi.

Starting Conditions of Synchronous Machines

BY ALFRED HAY

Professor of Electrical Technology, Indian Institute of Science

AND

F. N. MOWDAWALLA

INTRODUCTION

IN view of the growing popularity and importance of the synchronous motor as one of the standard types of motor available for power distribution purposes, and its increasing use as a means of improving the power factor of a load, no apology seems necessary for a paper containing a detailed study of the behavior of such a motor during what has always been regarded as a somewhat critical period—*viz.*, the period when the motor is being accelerated from rest to synchronous speed. The subject is by no means a new one, and has already been dealt with by several writers, not, however, in a manner sufficiently thorough and exhaustive to make further contributions to it superfluous, and one of the main objects of the present paper is to explain a number of hitherto somewhat obscure points, and to draw attention to others which have not previously been noticed.

REVIEW OF PREVIOUS WORK ON THE SUBJECT

The earliest paper specially devoted to a study of the starting conditions in synchronous machines appears to be one read in 1912 before the American Institute of Electrical Engineers by C. J. Fechheimer.[1] In this the author, after some general introductory remarks, gives an account of experiments made to determine (1) the relation connecting the starting torque with the impressed potential difference under various conditions and (2) the variation of torque, current and power factor with speed, while the rotor is accelerated from rest, a constant potential difference being maintained across the stator terminals. The experimental results are embodied in an interesting series of curves. Among the questions discussed by the author are the desirability or otherwise of keeping the field circuit open during the acceleration period, and the tendency of certain synchronous machines to run in the neighborhood of half the speed of synchronism. Fechheimer's paper gave rise to a very interesting discussion.

In 1913 E. Rosenberg[2] read a paper before the Institution of Electrical Engineers, on Synchronizing machines in which he considered, among other things, the occurrences during the starting period, and discussed in some detail the behavior of the machine towards the end of the acceleration period, just before it is pulled into synchronism. It may be mentioned that in the discussion on Fechheimer's paper, it was stated by B. G. Lamme that it was "difficult to see just what is going on in the motor at the instant it pulls into synchronism." So far as the authors are aware, Rosenberg's was the first attempt to furnish a detailed explanation of the action in question.

The next contribution to the subject is one by F. D. Newbury, in the form of a paper read before the American Institute of Electrical Engineers in June 1913.[3] The main interest of this paper lies in the oscillographic records which are given of the starting period.

In December 1917 the authors of the present paper published, in the *Journal* of the Indian Institute of Science, an account of some experimental investigations of the occurrences during the starting period of a synchronous machine, and a full theoretical discussion of the type of induction motor whose stator is supplied with polyphase currents, and whose rotor is provided with a single-magnetic-axis winding. As will be seen later, the theoretical results obtained explain in a satisfactory manner certain striking peculiarities exhibited by the machine during the starting period.

The most recent addition to the literature of the subject is an article by Theo. Schou in the *Electrical World* of April 6th, 1918 (Vol. 71, p. 714). In this article the author points out that a satisfactory self-starting synchronous motor should partake of the characteristics of both an induction motor and an alternator, and should present features of design intermediate between these two classes of machines. He accordingly advocates the use of a shorter air gap and longer polar arc than are customary in alternators of standard design. He further suggests the use of materials having a pronounced skin effect for the squirrel-cage windings of self-starting synchronous motors[4] and points out the advantages of fractional-pitch windings in reducing the troubles arising from dead points.

Presented at a joint meeting of the Institution of Electrical Engineers, and the American Institute of Electrical Engineers, Calcutta, India, January 2, 1919.

1. C. J. Fechheimer, PROCEEDINGS of the American Institute of Electrical Engineers, Vol. 31, pp. 305 and 1942 (1912).

2. E. Rosenberg, "Self-synchronizing Machines." *Journal* of the Institution of Electrical Engineers, Vol. 51, p. 62 (1913).

3. TRANSACTIONS of the American Institute of Electrical Engineers, Vol. 32, p. 1509.

4. The utilization of the skin effect in the rotor conductors of induction motors was patented by H. M. Hobart in 1900.

Torques Concerned in Accelerating the Motor and in Pulling it into Synchronism

The self-starting synchronous motor is accelerated and finally pulled into synchronism by the action of a number of torques, differing widely from each other, and the resultant effect of which will largely depend on their relative importance. Cases may arise where, owing to the preponderance of a certain type of component torque, it may be impossible to get the machine to run up to synchronous speed. Again, the torques concerned in the initial acceleration of the rotor are quite distinct from the torque which finally pulls it into synchronism. The authors are of opinion that no really clear understanding of the occurrences during the starting period is attainable without a detailed study of the various torques which act on the rotor during that period. It will accordingly be necessary to consider

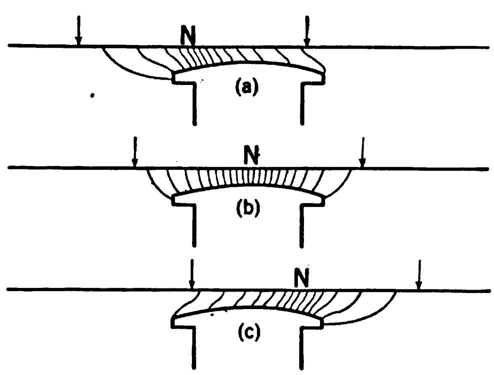


Fig. 1—Flux Distributions for Different Relative Positions of Stator Field and Magnet Poles

the nature of the various torques concerned. These torques may be classified as follows:

1. Torque due to varying magnetic reluctance (synchronous torque.)
2. Torque due to hysteresis.
3. Torque due to starting squirrel-cage or damping coils if present.
4. Torque due to currents induced in the field winding, if this winding is closed.
5. Torque due to eddy currents.

1. Torque Due to Varying Magnetic Reluctance

It is a well known general principle of electromagnetism that any electromagnetic system which includes a movable member tends to assume a configuration which corresponds to minimum reluctance and therefore maximum flux. Displacements of the movable member from the position of minimum reluctance call into play forces tending to restore it to that position. The application of this general principle to the special case of a salient pole rotor, which is acted on by the rotating field of the stator, will be easily understood by reference to Fig. 1. In this figure, three different positions of one of the rotor poles are shown relatively to the stator polar surfaces. The center of the stator polar surface is in each case marked with the letter N. In Fig. 1B, the relative positions of the rotor and stator polar surfaces correspond to minimum reluctance, and from the symmetry of flux distribution it is immediately obvious that there is no tangential pull on the rotor. In Fig. 1A, the rotor pole is shown displaced from the position of minimum reluctance in one direction, and in Fig. 1C in the opposite direction. If we bear in mind that the dynamical stresses correspond to a tension along the lines of force and a pressure at right angles to them, it is easy to see that in Fig. 1A there is a tangential force acting on the pole from right to left, while in Fig. 1C it acts from left to right. If we now suppose that the stator polar surfaces travel past the pole in a direction from left to right, then the successive positions will be those shown in Fig. 1. For every displacement of the stator polar surface to one side of a rotor pole, there will be an equal displacement to the other side, and the forces corresponding to equal displacements in opposite directions will be equal and opposite. Thus the rotating field will exert an alternating torque on the rotor, and the positive and negative half-waves of this torque will be equal. The frequency of the torque will be equal to twice the supply frequency multiplied by the motor slip, and so long as the motor slips, the mean value of the alternating torque due to varying magnetic reluctance will be zero. The only effect of this torque is to throw the rotor into forced vibrations, having a frequency equal to that of the torque. Owing to the large moment of inertia of the rotor the vibrations will be imperceptible for large values of the slip, *i. e.*, during the greater part of the acceleration period. When, however, the slip has become sufficiently small and in consequence the frequency of the torque sufficiently low, the amplitude of the rotor oscillations will become marked, and will increase with decreasing slip.

Summing up, we see that the torque due to variable magnetic reluctance is for all speeds below synchronism an alternating torque consisting of equal positive and negative half-waves, and hence having a zero mean algebraic value. It is therefore quite inoperative so far as steady acceleration of the rotor is concerned, and only produces equal periodic accelerations and retardations, *i. e.*, it causes oscillations of the rotor. The period of these oscillations is determined by the rotor slip, and steadily increases with decreasing slip. At the same time, the amplitude of the oscillations increases.

The graph of the varying magnetic reluctance torque expressed as a function of the speed is shown in Fig. 2A. For all speeds below synchronism its mean value is zero, while at synchronism it is capable of assuming any positive or negative value between definite limits. Since the speed of synchronism is the only speed at which this torque has a value differing from zero, we may conveniently refer to it as the *synchronous torque*.

2. Torque Due to Hysteresis

In dealing with the torque due to varying magnetic reluctance, we have neglected the effect of hysteresis. It now becomes necessary to take this into account. Owing to hysteresis the rotor will tend to retain more or less strongly the effects of previous magnetizations. Thus referring to Figs. 1A and 1C, if hysteresis were absent, the magnitudes of the torques in these two cases would be equal. Owing, however, to the fact that in the position of the rotating field corresponding

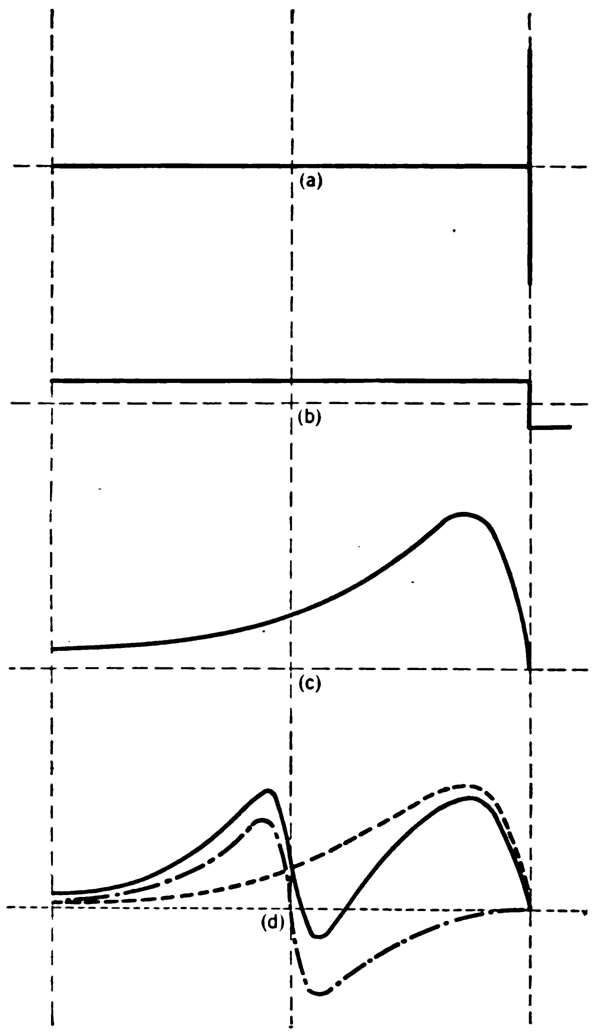


Fig. 2—Torque-Speed Curves

to Fig. 1A the magnetization of the rotor is increasing from a lower to a higher value, while in position Fig. 1C it is decreasing from a higher to a lower value, the actual flux in Fig. 1C will be higher than that in Fig. 1A. The same applies to each pair of corresponding or equidistant positions on opposite sides of the position of maximum flux shown in Fig. 1B. For any such pair of positions, the driving torque is greater than the retarding torque. The effect of hysteresis is thus seen to be the production of a disparity between the positive and negative half-waves of the varying magnetic reluctance torque, the positive half-waves being uniformly larger than the negative ones. This effect is equivalent to raising the magnetic reluctance torque waves above the axis of time, *i. e.*, to the addition of a steady driving torque to the alternating magnetic reluctance torque. The torque due to hysteresis is thus seen to be a steady driving torque and is instrumental in producing acceleration of the rotor. It is to be noted that, assuming the flux per pole to remain constant during the acceleration period, the hysteresis torque has the same value for all speeds below synchronism. If the speed were made to pass through synchronism to higher values, the hysteresis torque would undergo reversal at synchronism.

The graph of the hysteresis torque as a function of the speed is shown in Fig. 2B.

3. Torque Due to Starting Squirrel-Cage or Damping Coils if Present

Little need be said about this torque, which may be called the induction motor torque, as everybody is familiar with the relation connecting the torque and speed of an induction motor. The squirrel-cage of a self-starting synchronous machine forms the rotor winding of an induction motor whose stator windings are represented by the armature; the relation connecting torque and speed will be of precisely the same nature as in an induction motor.

The graph of this torque as a function of the speed is of the well-known form shown in Fig. 2C.

The method of varying the torque-speed curve of an induction motor by the introduction of resistance into the rotor is also well known. The effect of introducing resistance is to cause a shearing of the torque speed curves backwards towards the origin, the maximum torque remaining unaffected in value, but occurring at a lower speed. If a very powerful torque is necessary at starting, it is advisable to use a high-resistance squirrel-cage. On the other hand, with such a squirrel-cage the speed to which the motor finally settles down corresponds to a large slip, and this, as will be seen later on, makes it more difficult to pull the rotor into synchronism. The ideal arrangement would be one in which the squirrel-cage resistance at starting is such as to give maximum torque, the resistance then automatically decreasing with increase of speed in such a manner that at each speed maximum torque is maintained, until finally the lowest possible resistance is reached, corresponding to a very small slip. The use of the skin effect in conductors for automatically decreasing the rotor resistance with increasing speed has recently been proposed by Theo. Schou.[5]

4. Torque Due to Currents Induced in Field Winding, if this Winding is Closed

If the field winding be closed, the currents induced in it will give rise to a torque, and a careful study of the nature of this torque is essential to a clear understand-

5. Loc. cit.

ing of the occurrences during the starting period. The armature of the machine may again be regarded as forming the stator winding of an induction motor, of which the rotor winding is represented by the field coils. There is, however, this very important difference between the starting squirrel-cage and the field winding: the currents induced in the squirrel-cage are capable, according to their distribution in space, of giving rise to a field whose magnetic axes may occupy any positions whatsoever relatively to the center lines of the field poles; but the currents induced in the field winding can only produce a field whose magnetic axes are coincident with the center lines of the field poles. This is conveniently expressed by saying that the field winding is a "single magnetic axis" winding; because it can only produce a field having a single definite set of magnetic axes, namely, those corresponding to the center lines of the salient poles. Now a motor having a polyphase stator, but a single-phase or single-magnetic-axis rotor, exhibits certain striking peculiarities which differentiate it sharply from a motor in which both stator and rotor windings are polyphase. The earliest reference to this type of motor which the authors have been able to find occurs in a paper by H. Gorges[6]. Since such motors are not ordinarily used in practise, their characteristics do not seem to be very generally known, and have only occasionally been referred to. A complete analytical theory of this type of motor will appear in the A. I. E. E. TRANSACTIONS, for 1919. The torque-speed curve of such a motor is shown in Fig. 2D, and its most striking characteristic is the torque reversal which occurs over a certain range of speed in the neighborhood of half-synchronism. The analytical theory of this motor, is somewhat complicated, but the following general explanation based on a paper published in 1898 by F. Eichberg[7] may be useful. The currents induced in the single-phase rotor winding by the rotating field of the stator give rise to a field which, relatively to the rotor core, is a simple alternating or oscillating field. By a well-known transformation this oscillating field may be replaced by two equal and (relatively to the rotor core) oppositely rotating fields, the crest value of each rotating field being half the maximum crest value of the oscillating field. Now if the slip of the motor be s and if its speed of synchronism be denoted by n, the frequency of the rotor currents will be $s\,f$, where f is the frequency of supply, and the speed of its component rotating fields relatively to the rotor core will be $s\,n$, the speed of the rotor in space being $(1 - s)\,n$. Regarding the direction of rotation of the rotor as positive, the speed of one of the rotating fields relatively to the rotor core is $+ s\,n$, while that of the other is $- s\,n$. Hence the speeds of the rotor rotating fields *in space* are $s\,n + (1 - s)\,n = n$, and $- s\,n + (1 - s)\,n = (1 - 2\,s)\,n$. The interaction between the stator field, and the first rotating component of the rotor field, whose speed n in space is the same as that of the stator field, gives rise to a torque in every respect similar to that of an ordinary induction motor with polyphase windings on both stator and rotor. The second rotating component of the rotor field, whose speed in space is $(1 - 2\,s)\,n$, is clearly incapable of reacting with the stator field in such a manner as to give rise to a resultant torque; for, owing to the difference of speed, the relative position of the fields is constantly changing, periodically passing through a succession of cycles during each of which the average algebraic value of the torque is zero. Although incapable of torque production by interaction with the stator field, the second rotating component of the rotor field is capable of giving rise to a torque by different kind of action. In sweeping across the stator conductors, it induces in them e.m.fs. of frequency $(1 - 2\,s)\,f$, and these produce currents of the same frequency in the stator windings and the circuit external to them (represented by the mains and everything connected across them generators, motors, lamps, etc.). Since the total impedance external to the stator windings is extremely small in comparison with that of the windings themselves, the result, so far as the currents of frequency $(1 - 2\,s)\,f$ are concerned, is nearly the same as if the stator windings were short-circuited. The currents give rise to a rotating field whose speed $(1 - 2\,s)\,n$ in space is the same as that of the inducing rotor field, and the interaction of these two fields whose relative space position is invariable, results in the production of a torque. To fix ideas, we may think of the second component of the rotor field as produced by a polyphase winding on the rotor supplied with suitable polyphase currents having a frequency $s\,f$, and of the rotating field due to this as inducing currents of frequency $(1 - 2\,s)\,f$ in the stator windings. The arrangement would then be equivalent to a polyphase motor whose primary is represented by the rotor and whose secondary is represented by the stator. The slip of this imaginary motor would be $(1 - 2\,s)$ and so long as s is less than $\frac{1}{2}$, the slip and torque would be positive. Zero slip would occur at $s = \frac{1}{2}$, *i. e.*, at half the speed of synchronism. Beyond this point the slip and torque would assume negative values.

The resultant torque of the motor would be obtained by taking the algebraic sum of the torques due to the two oppositely rotating components of the oscillating rotor field. This torque is represented by the full line curve in Fig. 2D, the dotted and chain-dotted curves corresponding to the component torques due to the two rotating components of the rotor field.

If we suppose that the torque arising from the current in the field winding is large in comparison with the other torques acting on the rotor, so that the dominant effect is that due to the field winding, then it is evident that the torque reversal which occurs at half-synchron-

6. H. Gorges: "Ueber Drehstrommotoren mit verminderter Tourenzahl, *Elektrotechnische Zeitschrift*, Vol. 17, p. 517 (1896).

7. F. Eichberg, *Zeitschrift fur Elektrotechnik* (Wein), Vol. 16, p. 578 (1898).

ous speed will tend to make the machine run in the neighborhood of that speed, and it will then be impossible to run the machine up to full synchronism.

In the discussions which have taken place regarding the tendency of the machine to settle down to a speed in the neighborhood of half-synchronism, erroneous views have frequently been expressed. Some engineers appear to hold the opinion that the machine *locks* into exact half-synchronism. As we have seen, the speed to which it settles down, although near half-synchronism, is not definite, and may, according to the special circumstances of each case, be anywhere in the neighborhood of that speed. It is no more correct to say that the machine locks into half-synchronism, than it would be to say that an ordinary induction motor locks into full synchronism.

5. Torque Due to Eddy Currents

If the field structure is laminated throughout, the torque due to eddy-currents will be insignificant. The case is otherwise, however, with solid field poles in which large eddy-currents may arise. If we were to imagine the rotor replaced by a solid cylinder of conducting material, then the rotating field of the stator would give rise to rotating eddy-current sheets in the conducting cylinder, and the axes of such current sheets[8] would follow the axes of the rotating stator field. There would in this case be perfect freedom of motion of the axes of the current sheets relatively to the rotor, and this condition is closely approximated to in an ordinary squirrel-cage winding. If we next suppose that the conducting cylinder is cut up into a number of sectors by radial barriers of insulating material, then the freedom of motion of the axes of the current sheets relatively to the rotor would be largely destroyed, and these axes could only swing through an angular distance not exceeding the angular width of a sector. Now this is approximately the case corresponding to a salient pole rotor with solid poles. In such a rotor, owing to the restriction imposed on the free development of eddy currents by the relatively large spaces between the field poles, the axes of the eddy currents can only travel through a relatively short distance. If the axes could not travel at all, the arrangement would be identical with that of a rotor having a single magnetic axis winding; while if the axes could travel with perfect freedom, it would be identical with that of a squirrel-cage rotor. Hence we see that the torque due to eddy currents in the solid field cores will partake partly of the nature of the torque due to a single magnetic axis rotor winding, and partly of that due to an ordinary polyphase rotor. The single magnetic axis effect is, however, in many cases found to predominate, and considerable difficulty may then be experienced in getting the rotor to pass well beyond half-synchronous speed.

8. By the axes of the current sheets are meant the lines along which the current density is zero or the lines with which all the individual current filaments are linked.

Pulling into Synchronism

Of the various torques concerned in accelerating the rotor from rest to synchronism, three, namely the induction motor, the single-magnetic-axis and the eddy current torque, are functions of the speed, and may hence conveniently be referred to as the speed torques. Let us suppose that by the action of the speed and hysteresis torques the rotor has been brought to a speed not far removed from synchronism. Since in the neighborhood of synchronism, the speed torques rapidly decrease with decreasing slip—as shown in Fig. 2—and assume zero values at synchronism, it is evident that these torques would never be able to bring the rotor up to full synchronism; and the hysteresis torque is generally much too weak to effect this. The rotor is finally pulled into synchronism by the varying magnetic reluctance torque, and is maintained at synchronous speed by the same torque, all the other torques vanishing at that speed. As already explained, the varying magnetic reluctance torque may for this reason be conveniently termed the synchronous torque, and we shall in what follows refer to it as such.

We have already seen that the synchronous torque is an alternating torque having a zero mean value for all speeds other than that of synchronism, and is thus incapable of exerting any steady driving or accelerating effect so long as the speed of the rotor is below synchronism. The frequency of the synchronous torque is given by $2\,s\,f$., and the forced oscillations of the rotor to which the synchronous torque gives rise have the same frequency as the torque itself. Now the rotor speed oscillations call into play a further alternating or oscillating torque, owing to the fact that the speed torques change with the speed of the rotor. The speed torques may for small values of the slip be taken to be proportional to the slip, and hence their changes to be proportional to the changes in the speed. The effect is the same as if we were to substitute for the fluctuating speed torques a constant torque equal to the sum of the mean values of the speed torques, together with an oscillating torque whose amplitude is proportional to that of the speed fluctuations.

For the sake of simplicity we shall assume the speed fluctuations to obey the simple harmonic law. They may then be graphically represented in a vector diagram by the projections on the vertical axis of the vector $O\,V$ in Fig. 3, this vector rotating at $s\,f$, revolutions per second. The instantaneous projection of $O\,V$ gives the difference between the instantaneous speed and the mean speed. Since the oscillating component of the speed torques may, as we have seen, in the neighborhood of synchronism be taken to be proportional at every instant to the difference between the instantaneous and the mean speed, and since increase of speed produces decrease of speed torques, it is evident that the oscillating or fluctuating component of the speed torques may be represented by a vector $O\,F$ in direct phase opposition to $O\,V$. Next, if we assume that the

alternating synchronous torque is also a simple harmonic function of the time, then the resultant of the synchronous torque and the oscillating component of the speed torques will give us the alternating torque which gives rise to the periodic accelerations and retardations of the rotor. The phase of this resultant torque is easily determined; for since its zero value must occur at the instant of maximum speed, it is evident that the vector $O\,R$, which represents the resultant torque, must be 90 deg. ahead of $O\,V$, as shown in Fig. 3. Lastly, the synchronous torque vector $O.S$ is obtained by subtracting from the resultant accelerating torque $O\,R$ the oscillating component $O\,F$ of the speed torques. The angular velocity of all the vectors in the diagram of Fig. 3 is directly proportional to the slip, being, in fact, equal to $4\,\pi\,s\,f$.

Let ω denote the excess of the instantaneous rotor speed over the mean speed (corresponding to the vertical projection of $O\,V$ in Fig. 3), and let y stand for the

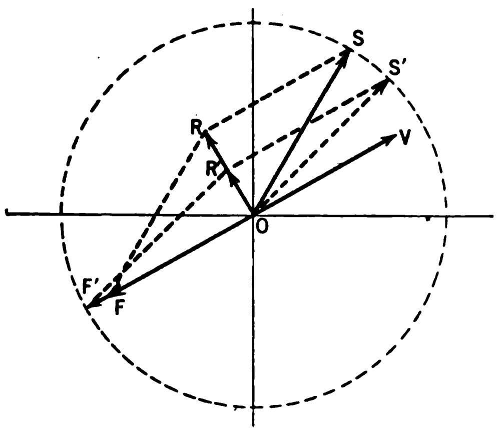


Fig. 3—Vector Diagram of Speed Fluctuations and Torques

instantaneous resultant accelerating torque (vertical projection of $O\,R$). Then, if K is the moment of inertia of the rotor,

$$\text{or} \qquad y = K\,\frac{d\,\omega}{d\,t},$$

$$d\,\omega = 1/K\,y\,d\,t$$

and hence, taking as the origin of time the instant at which ω is zero,

$$\omega = 1/K \int y\,d\,t,$$

from which it is seen that the amplitude of the speed fluctuation $O\,V$ is proportional to the time-integral over a quarter-period of the resultant accelerating torque; or, since the period of this torque varies inversely as the slip, $O\,V$ is proportional to $\dfrac{O\,R}{s}$

By means of the vector diagram of Fig. 3 we can easily show that the amplitude of the speed fluctuations must increase with decreasing rotor slip. For, assuming the diagram to represent the conditions prevailing at a given mean speed, if the mean speed increases, $O\,R$ must decrease; for if it were to remain constant, then owing to the increase of its period due to the decrease of slip, its time-integral over a quarter-period would be increased, and $O\,V$, which is proportional to this time-integral, would increase. This again would cause $O\,F$ ($S\,R$), which is proportional to $O\,V$, to increase; but since the length $O\,S$ is constant, an increase of $S\,R$ could only be brought about by a decrease of $O\,R$ (as shown by the dotted lines $O\,S'$ and $R'\,S'$ in the figure). It follows *a fortiori* that $O\,R$ could not increase with increase of mean speed.

We thus see that as the mean speed of the rotor gradually increases, the vector $O\,V$ undergoes steady elongation, the vector $O\,F = S\,R$ a similar steady elongation ($O\,F$ is proportional to $O\,V$) and the vector $O\,R$ a steady contraction. The vector $O\,S$ remains fixed in magnitude, but gradually approaches $O\,V$. At the same time the angular velocity of all the vectors in the diagram steadily decreases. If we were to consider the actual paths traced out by the extremities of the vectors during the last few cycles preceding synchronism, we should find that V traces out a spiral path opening outwards, F a similar path, R a spiral path contracting inwards, while S continues to move in its original circular path. Just before synchronism is reached, $O\,V$ is moving with extreme slowness and $O\,S$ is only very slightly in advance of it. As $O\,V$, having passed through the horizontal position, moves into the first quadrant, its projection gradually increases until the value of this projection when added to the mean rotor speed gives the speed of synchronism. At this instant all the torques have disappeared with the exception of the synchronous torque.

It is clear that at the instant when synchronism is first reached the synchronous torque cannot be less than the total torque resisting the motion. For, if such were the case, then balance of the total driving and resisting torques must have taken place at some instant preceding synchronism, and such balance would have prevented any further increase of speed, *i. e.*, it would have prevented the rotor from reaching synchronism. Hence at the instant when synchronism is reached, the synchronous torque must either equal or exceed the total resisting torque. In the first case, the rotor will steadily maintain synchronous speed. In the second, further acceleration will take place, and the rotor will settle down to the steady speed of synchronism only after a number of oscillations, the final position which it takes up relatively to the stator poles being such that the synchronous torque arising from the displacement of the magnetic axes of the stator and rotor is exactly equal to the total resisting torque. Whether the rotor comes up to synchronous speed quietly without oscillations, or whether such oscillations take place before it finally settles down to the steady speed of synchronism, the running will correspond to stable conditions. For

in either case a momentary increase of speed results in decrease of driving torque, and a momentary decrease of speed in increase of driving torque. The momentary changes in the driving torque which arise during speed fluctuations, are due partly to changes in the synchronous torque, which tend to check such fluctuations, and partly to the reappearance of the speed and hysteresis torques, which have a similar effect.

Open Versus Closed Field Windings at Starting

The advisability or otherwise of closing the field windings at starting has been repeatedly discussed. The danger of breaking down the insulation by the high voltage induced in the field windings when the stator circuits are first connected to the mains must be taken into account. Although this danger is entirely avoided by short-circuiting the windings before the stator is connected to the mains, there is no doubt that, from the point of view of initial torque and rapidity of starting, it is inadvisable to have the field circuit closed. The effect of closing field windings is similar to that of reducing the resistance of the squirrel-cage or eddy current path,—a procedure which is well-known to lower the initial torque. Again, as the neighborhood of half-synchronism is approached, the powerful single-axis rotor effect may seriously affect the acceleration of the rotor, and may frequently entirely prevent the machine from attaining any speed greatly exceeding that of half-synchronism. In order therefore to increase the acceleration of the rotor during the early stages of the starting process, the field should be kept open; any risk of breaking down the insulation may be guarded against by the use of a suitable field break-up switch.

Now although it is advisable to keep the field circuit open during the initial stages of the starting operation it by no means follows that it would be equally advantageous to keep it open until the machine has been pulled into synchronism. The slip with which the rotor ultimately tends to run under the action of the speed torques will depend on the resistance of the circuits in which the currents giving rise to the speed torques circulate. By lowering this resistance the torque will be momentarily raised and the speed increased. Now closing the field circuit would be equivalent to such reduction of resistance, so that the short-circuiting of the field during the final stages of the starting operation will cause the mean rotor speed to approach more closely to the speed of synchronism than would otherwise be the case. There is thus a distinct advantage in closing the field circuit during the final stages of the starting operation, after the rotor speed has reached a value not differing greatly from synchronism. Cases may in fact arise where a machine with its field open might refuse to pull into synchronism, but could be made to do so by closing the field circuit. This conclusion has been verified experimentally. A certain machine was started with its field open, the rotor potential difference being so low that the rotor settled down to a speed below synchronism, and refused to pull into synchronism. The moment, however, that the field circuit was closed, the rotor locked into synchronism.

Oscillations in Stator Current During the Period Immediately Preceding Synchronism

It is well known that as the speed of synchronism is approached violent fluctuations in the stator current gradually become noticeable. These are indicated in Fig. 5 of Rosenberg's paper, and are easily accounted for. So long as the speed is below synchronism, the field poles are slipping past the stator poles, and periodic fluctuations are taking place in the reluctance accompanied by corresponding fluctuations of reactance which throw the stator current into oscillations. The frequency of these oscillations being $2\,s\,f$ (since the reluctance returns to the same instantaneous value after the pole has moved through a distance equal to the pole-pitch) they are not noticeable at low speeds, and only become apparent when the slip has become sufficiently small.

Some Experimental Results

(*a*) *Relations Connecting Stator Potential Defference with Stator Current, Stator Input and Power-Factor, Rotor Speed and Field E. M. F. when Field is Open-Circuited.* The experiments embodied in the series of curves given below were carried out on a four-pole, five-kw. three-phase converter designed for a continuous current voltage of 100–130 volts at a speed of 750 rev. per min. This machine had laminated main poles, was fitted with commutating poles, but had no special starting devices. While the experiments about to be described were being carried out, the brushes were entirely removed from the commutator. Before each set of readings the machine was allowed to run light for a sufficiently long time to get the bearings into a steady state.

In the first set of experiments, the results of which are exhibited graphically in Figs. 4 and 5, a number of gradually increasing potential differences were applied to the rotor slip rings, and after the speed corresponding to any given potential difference had settled down to a constant value, readings of the speed, current, power, etc., were taken when the potential difference had been raised sufficiently to enable the machine to lock into synchronism, it was still further increased, and then a second series of readings, corresponding to decreasing values of the potential difference was obtained. In the illustrations both the ascending and descending branches of the various curves are given.

Fig. 4 shows the relations connecting speed and field e. m. f. with stator potential difference. Below a potential difference of about 15 volts across the slip rings the machine would not run at all. The speed then gradually increased with the potential difference,

the increase becoming much slower beyond a certain point, and at a slip-ring potential difference of about 45 volts the machine was able to lock into synchronism. During the descending set of readings, synchronism was maintained down to a voltage of about 35 volts. Below this point the speeds obtained with given voltages were found to be uniformly higher than those corresponding to the ascending branch of the curve. Since, as shown by Fig. 5, the power supplied to the machine was found to be lower for decreasing values of the potential difference, in spite of the higher value of the speed, it is to be inferred that for decreasing values of the potential difference the resisting torque was uniformly less. This would indicate a decrease in the frictional resistances, probably due to the temperature of the bearings being higher during the descending set of readings than during the ascending set.

The changes in the field e. m. f. are related to those

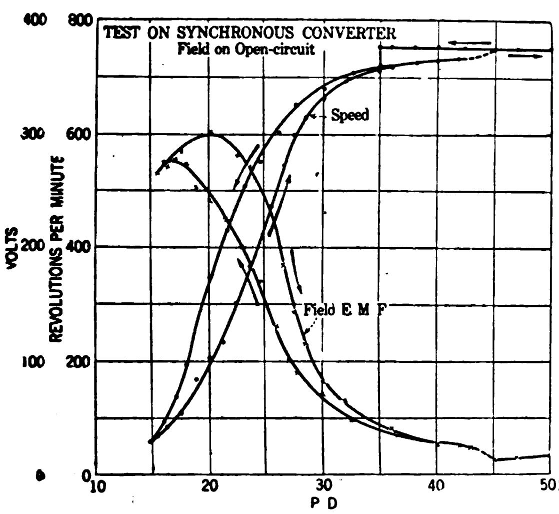


Fig. 4—Curves Connecting Speed and Field E.M.F. with Stator P.D. when Field is Open-Circuited

in the speed. The field e. m. f. may be regarded as proportional to the product of two factors, namely the maximum flux per pole and the slip. At first the field e. m. f. rises with increase of potential difference, indicating that the increase of flux is more important than the decrease of slip. Beyond a certain point the decrease of slip is more important than the increase of flux, and the field e. m. f. begins to decrease. It does not vanish at synchronism, indicating that there is either swaying or pulsation of the flux which enters the main poles. Since for descending values of the potential difference the speed is uniformly higher and hence the slip lower than for ascending values, we should expect the field e. m. f. to be uniformly lower in the former case, and the curve of field e. m. f. shows that such is the case.

Fig. 5 shows the relations connecting stator current, stator power and power-factor with potential difference. The difference between the ascending and descending branches of the power or input curve has already been referred to. It must be remembered that when the machine is not running synchronously, its behavior is similar to that of an induction motor. Hence, owing to the lower resisting torque during the descending set of readings we should expect a smaller current and also a lower power-factor (as is at once evident from consideration of the circle diagram) than during the ascending set; and the curves of Fig. 5 fully confirm this.

(*b*) *Relations Connecting Stator Potential Difference with Speed and Field Current, when the Field Circuit is Closed.* Figs. 6 and 7 give the connection between potential difference and speed when the field circuit is closed through various resistances, and in Fig. 6 the curve corresponding to the field on open-circuit, previously shown in Fig. 4, is repeated for the sake of comparison.

When the field was on dead short-circuit, the machine refused to run up to anything like synchronous

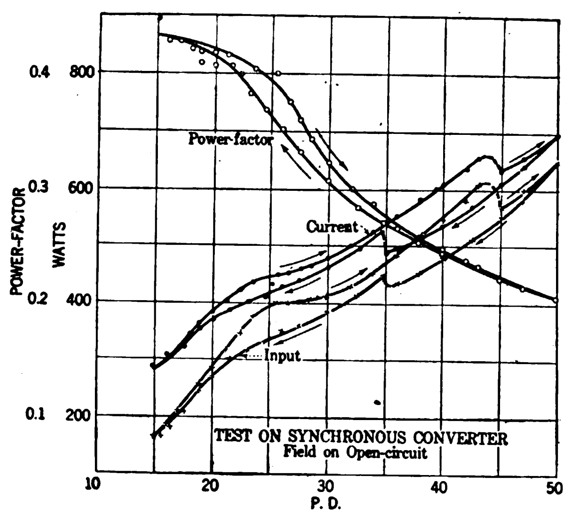


Fig. 5—Curves Connecting Stator Input, Current and Power Factor with Stator P.D. when Field Is Open-Circuited

speed, and seemed to approach asymptotically a speed somewhat above half-synchronism.[9] The explanation of this fact has already been given (reference may be made in this connection to Fig. 2D).

The curves of Fig. 7 show that by the introduction of a suitable amount of resistance into the field circuit the tendency of the machine to settle down to a speed in the neighborhood of half-synchronism may be overcome, and that the machine may be made to lock into synchronism. This result may be explained as follows. Considering the complete torque-speed curve of an induction machine over the entire range of slip, positive and negative, we may regard the point of zero slip as dividing this curve into two branches, one of which corresponds to positive values of the slip, and the other to negative values. If we now suppose resistance to be

9. Incidentally the fact that the machine reached a speed in excess of half-synchronism definitely disposes of the erroneous view previously referred to that the machine tends to lock into exact half-synchronism.

introduced into the rotor circuit, then as is well known, the result is to produce a shearing of the two branches of the torque speed curve in opposite directions from the point of zero slip. Referring now to the torque-speed curves of Fig. 2D, it must be noticed that the point of zero slip for the chain-dotted curve corresponds to half-synchronism, while for the dotted curve the point of zero slip is at full synchronism. From this it follows that the introduction of resistance will in the region between half and full synchronism cause a shearing of the dotted and chain-dotted curves in opposite directions, the dotted curve being sheared from left to right, while the chain-dotted one is sheared from right to left. It is easy to see that this will cause a rise of the minimum in the resultant curve (the full line curve of Fig. 2D), and if the resistance remains sufficiently large the minimum resultant torque will assume a positive value, so that the driving torque will be positive over the

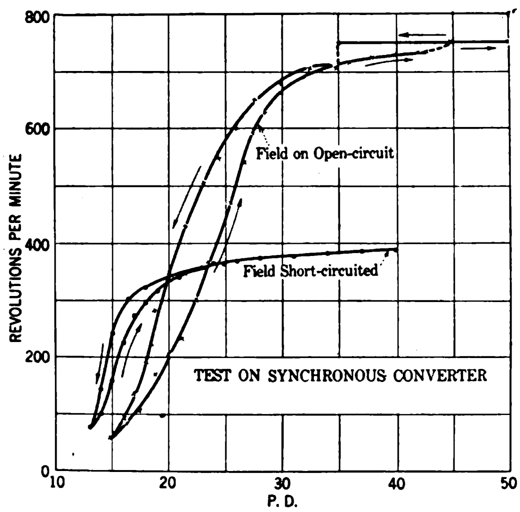


Fig. 6—Curves Connecting Speed with P.D. when Field Is (a) Open Circuited, and (b) Short-Circuited

entire range of speed from zero to synchronism. The shearing of the dotted and chain-dotted curves in opposite directions in the region between half and full synchronism is, however, only one of the causes concerned in suppressing the negative portion of the resultant torque-speed curve, and besides this there is another cause. The dotted curve is the torque-speed curve of an induction motor whose stator is supplied at constant potential difference and frequency; whereas the chain-dotted curve is the curve of an imaginary induction motor whose stator is supplied at variable potential difference and variable frequency, the potential difference being proportional to the frequency. Now the introduction of resistance into the field windings is equivalent to the introduction of resistance into the primary winding of the imaginary motor (since the primary winding of this imaginary motor is represented by the field winding) and is thus equivalent to a reduction of the potential difference across its terminals. This will result in a reduction of all the ordinates of the chain-dotted curve. While therefore, the introduction of resistance into the field circuit results in a simple shearing of the dotted curves from right to left unaccompanied by any change in the values of the ordinates, the effect on the chain-dotted curve is a two-fold one, namely, a shearing from left to right accompanied by a

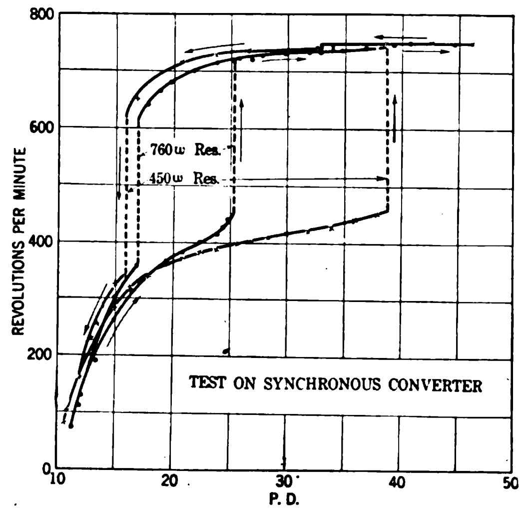


Fig. 7—Curves Connecting Speed with P.D. when Field Is Closed through External Resistance

shrinkage of the ordinates. This shrinkage of the ordinates will further help to suppress the negative portion of the resultant curve.

It will be noticed that in the curves of Fig. 6 which refer to the open-circuit and short-circuit conditions of the field, there are no discontinuities in the speed curves

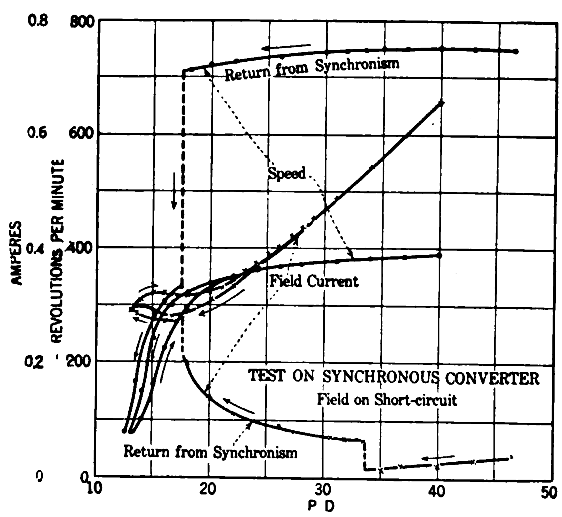


Fig. 8—Curves Connecting Speed and Field Current with P.D. when Field Is Short-Circuited

(except that which occurs at the instant of breaking from synchronism in the case of the open-circuit curve); whereas the curves of Fig. 7 show two well-marked discontinuities (one on each of the curves), in addition to the discontinuities at break from synchronism. These discontinuities are readily accounted for by considering

the shape of the resultant or full-line torque-speed curve of Fig. 2D. In the cases to which Fig. 7 refers the resultant torque-speed curve lies, as already explained, wholly above the axis of speed, all its ordinates being positive; but the curve has two maxima separated by a minimum. It is the existence of this minimum which causes the discontinuities in the speed curves. Stability of running can only be secured by working on a portion of the torque-speed curve which has a downward slope from left to right. With increasing potential difference and speed the point on the (varying) torque-speed curve corresponding to the stable running condition for the given potential difference gets displaced further and further to the right, until finally it reaches the minimum point on the curve. An increase of potential difference beyond the value corresponding to this minimum point results in a passage into the unstable region which lies between the minimum and the second maximum, and no stable running is possible in this region. It is only after the speed has passed beyond the second maximum of the torque-speed curve that stability can again be reached. The point where the discontinuity occurs along the ascending branch gives approximately the speed corresponding to minimum torque; while the discontinuity on the descending branch marks approximately the second maximum of torque. The first maximum of torque would correspond roughly to the lowest speed at which the machine will run.

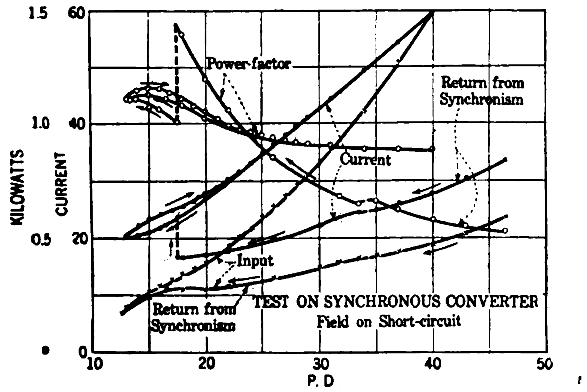


Fig. 9—Curves Connecting Stator Input, Current and Power Factor with P.D. when Field Is Short-Circuited

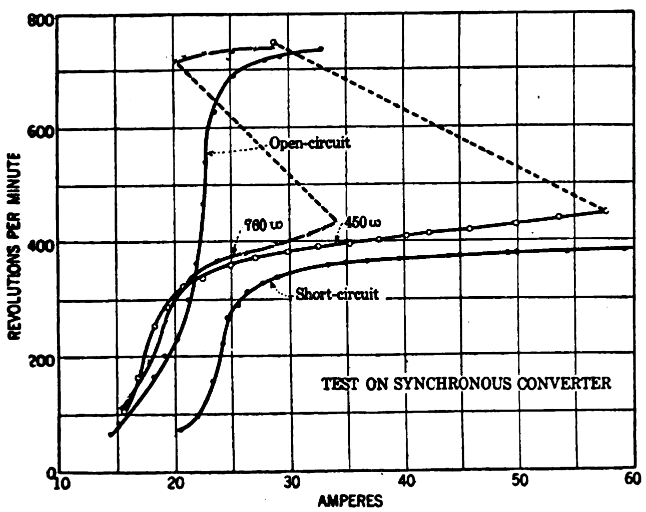


Fig. 10—Curves Connecting Speed with Stator Current under Various Conditions

In Fig. 8 are shown the relations connecting speed and potential difference, and field current and potential difference, with the field on dead short-circuit. Each curve is shown as having three branches. Two of these correspond to the values obtained by first increasing the speed to a certain value and then decreasing it. The third branch, marked "Return from synchronism" was obtained by first open-circuiting the field and raising the potential difference to a value sufficient to enable the machine to lock into synchronism, then short-circuiting the field and taking a set of readings while the potential difference was being decreased. The first two branches of the speed curve are identical with those shown in Fig. 6. The relations connecting current and power factor with potential difference are given by Fig. 9.

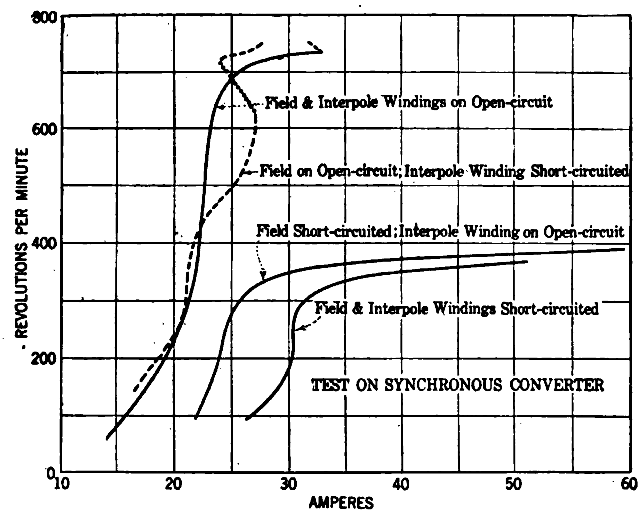


Fig. 11—Curves Connecting Speed with Stator Current under Various Conditions

Returning to Fig. 6, it will be seen that the machine starts with a lower potential difference when the field is short-circuited than when it is on open circuit; and this might at first sight appear to contradict the statement previously made regarding the advantage of starting with the field circuit open. Such, however, is not the case; for the real basis of comparison is not the potential difference applied to the stator, but the *current* taken by it. The relation connecting speed with current for the various arrangements tried is shown in Fig. 10, and it will be seen at once that the machine starts up with a considerably lower current when the field is open-circuited. If the field is closed through a resistance, there will be a certain value of this resistance which gives the best initial results, but even with this

value the current during the intermediate stages rises to a higher value than when the field is open-circuited. On the other hand, it will be noticed that with the field closed through a resistance high enough to allow of the machine being pulled into synchronism, a higher value of speed is reached with a given current than with the field on open circuit.

As the machine experimented on was provided with interpoles, it was thought desirable to try the effect of short-circuiting the interpole winding. In Fig. 11 are given four curves, two of which are for the sake of comparison reproduced from Fig. 10. It will be seen that the worst results are obtained with both main and inter-pole fields short-circuited, and that the short-circuiting of the interpole windings alone does not produce any very marked effect, and is not sufficient to prevent the machine from running up to synchronism.

Summary of Conclusions Reached

1. During the initial stages of the starting period the field should be kept open. If the induced voltage exceeds the limit of safety, a field break-up switch should be provided.

Closing the field circuit not only largely increases the current during the initial stages of the starting period, but may entirely prevent the machine from running up to synchronous speed. This is due to the single-magnetic-axis effect of the field winding.

2. If the field is kept closed and the machine only reaches a speed in the neighborhood of half-synchronism, there is no tendency to lock into exact half-synchronism.

3. There is a distinct advantage in short-circuiting the field after the field has reached a value not differing greatly from synchronism. This will greatly facilitate the final locking into synchronism.

BROADER TRAINING OF ENGINEERS

BY W. I. SLICHTER
Professor of Electrical Engineering, Columbia University

THE report of the Development Committee of the Institute as approved at the Lake Placid Convention, contained a section calling attention to the fact that "engineers do not participate as actively or as prominently in public affairs as they should and that both the public welfare and their own individual advancement would be promoted if this condition could be rectified."

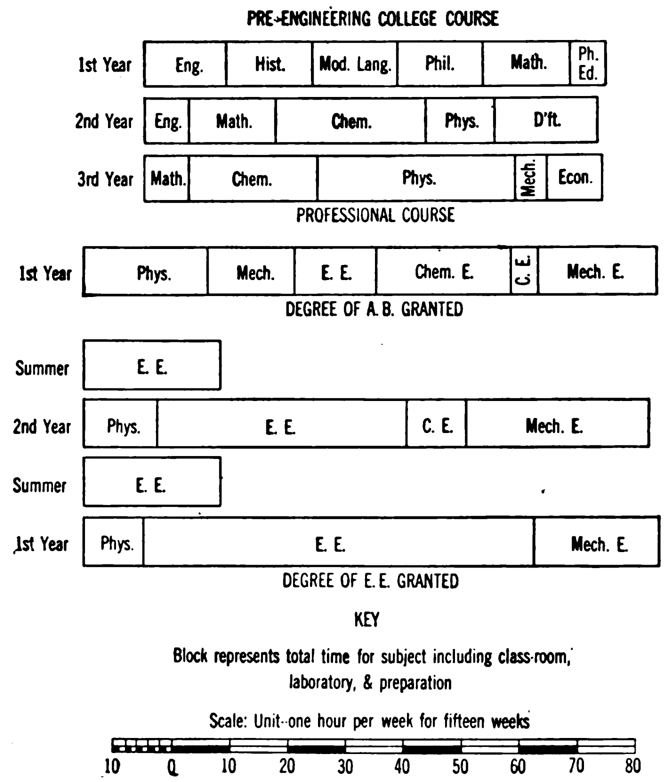
One of the reasons given for this condition was: "too great technical specialization in the engineering curricula of our technical schools and colleges which tend to narrow the vision of the engineering students."

To counteract this tendency it was stated that the Committee would welcome the establishment, at the earliest practicable date of a normal six years' collegiate course in engineering, two years of which at least should be devoted to training in the humane arts and sciences, while the last four should be devoted to a sound training in the sciences and in only the fundamentals of diversified engineering.

Since the Development Committee has called attention to this idea of broadening the training of the engineer, the membership of the Institute should be interested in investigating how such a scheme would work out in practise. To this end there is presented herewith a schematic diagram in a new form, so that he who runs may read, showing the new six year course for engineers which was inaugurated at Columbia University about four years ago. This method of presentation is interesting in itself and was designed to enable the busy Alumnus to grasp at a glance what the institution is doing to the younger engineers.

The diagrams show how the student's time is divided, three years in college and three years in professional work, and the subjects taken each year, weighted in proportion to the time assigned to them.

At the end of the first professional year, the fourth year of residence, the student receives an A. B. degree and here a process of natural selection occurs, the man not suited to engineering work usually decides to take



C. E., Civil Engineering. *Chem.*, Chemistry. *Chem. E.*, Chemical Engineering. *D'ft.*, Drafting. *Econ.*, Economics. *E. E.*, Electrical Engineering. *Eng.*, English. *Hist.*, History. *Math.*, Mathematics. *Mech.*, Mechanics. *Mech. E.*, Mechanical Engineering. *Mod. Lang.*, Modern Language. *Phil.*, Philosophy. *Phys.*, Physics. *Ph. Ed.*, Physical Education.

his sheepskin and go into general business, having had a well-rounded scientific education already. From here on the training becomes more special and at the end of the sixth year the candidate receives the appropriate professional degree, in this case, "Electrical Engineer."

Electric Propulsion on the Steamship Wulsty Castle

BY GEORGE B. PULHAM
Electrical Engineer, S. S. Wulsty Castle

THE Steamship *Wulsty Castle* is at present the only British electrically propelled seagoing ship in commission, and developments are being closely watched by certain prominent British shipping concerns which are keeping the electric ship propulsion proposition steadily in view.

The vessel is designed for a speed of 10 knots per hour, and for cargo carrying only, and is now trading, with other ships of Chamber's Castle Line, between

FIG. 1—THE BRITISH TURBO-ELECTRIC CARGO STEAMER *Wulsty Castle*

southern U. S. A. ports and Europe. She is capable of carrying some 6000 Imperial tons of cargo. Her length between perpendiculars is 356 ft. 3 in. (108.27 m.) beam 48 ft. 9 in. (14.86 m.) and the mean draft when fully loaded is approximately 24 ft. (7.31 m.). In the installation about to be described, two turbo alternators situated one each side of the 30 ft. by 45 ft. (9.14 m. by 13.71 m.), engine room, running in parallel, supply power to two main driving induction motors, which are situated amidships, and which in turn transmit power through double helical single reduction gearing to the single low-speed propeller shaft.

Boilers. Steam is generated in two cylindrical boilers of 13 ft. (3.96 m.) internal diameter by 11 ft. (3.35 m.) long, with 3 in. (76.2 m m.) internal diameter smoke tubes, and designed for a working pressure of 220 lb. per sq. in. The Howden's system of forced draught is used, and Schmidt type smoke tube superheaters are fitted. In addition to the standard marine mountings, "Diamond" tube blowers are installed for keeping the tubes clear.

Originally coal burning, the boilers were recently equipped with the White low pressure oil fuel system. Considerable trouble was caused, especially when burning inferior classes of oil, by heavy soot lodging on the superheater tubes inside the boiler tubes, thus obstructing the draught and materially interfering with the efficient working of the boilers. Keeping these tubes clear necessitated the frequent and liberal use of steam through the Diamond blowers. So serious did this matter become, and to such an extent did it impair the efficient running of the plant, that it was deemed advisable to remove a small percentage of the superheater tubes. This alteration was followed by good results, and by no appreciable drop in steam temperature, which approximately 550 deg. fahr. at the turbine stop valves. A feed heater is installed, through which the feed water returns to the boilers at a temperature of around 223 deg. fahr. A small donkey boiler, designed to work at 100 lb. pressure for driving cargo winches etc. in port is mounted between the two main boilers.

Turbines. In this brief article the writer does not propose to describe the Ljungström turbine[1] in detail,

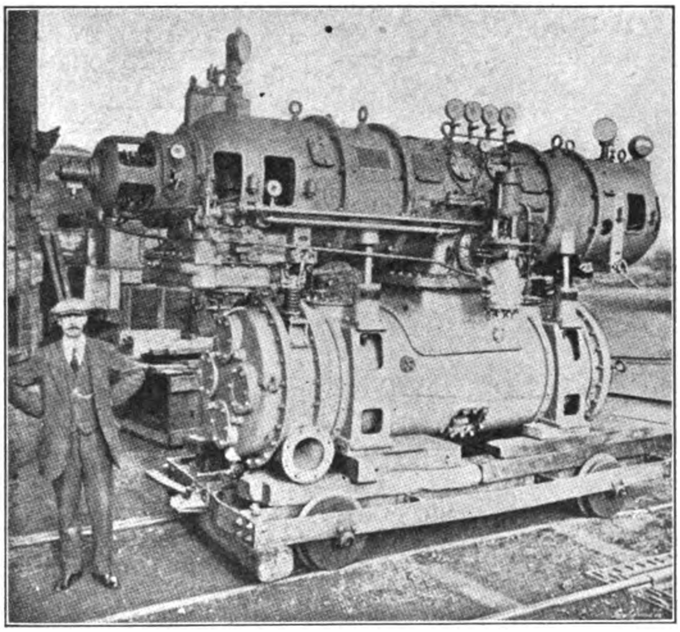


FIG. 2—LJUNGSTROM TURBO-ALTERNATOR AND CONDENSER

and will merely explain that this turbine is a radial-flow machine consisting of two disks carrying concentric intermeshing wings of reaction blading. Steam enters the blading near the center of the disks, and in passing from ring to ring outwards impells one disk in one direction and the other in the opposite direction, each disk being direct connected to an alternator shaft. Fig. 2 shows the port turbo-alternator and condenser of the *Wulsty Castle* leaving the works of the Brush

1. For detailed description of Ljungstrom turbine see *Engineering*, Vols. CV. and CVI, 1918.

Electrical Engineering Company to be placed on board. The exciter can be clearly seen on the extreme left. The condenser is of the "Contraflo" surface type and forms the bed plate of the complete turbo alternator.

A Ljungstrom turbo alternator in the course of erection is shown in Fig. 3. In addition to ventilating the alternator windings, the ventilating fans, one of which can be seen near the slip rings Fig. 3, furnish the air required at the boiler furnaces. After cooling the windings, the heated air is passed along to the Howden's forced draught system where it maintains approximately 9/16 in. of draught at the furnace doors. The main lubricating oil pump and governor gear are both driven by the gear wheel on the extreme right.

these two alternators come into synchronism automatically, an ammeter joined in series with their fields (shown on the right of Fig. 2) indicating when this has occurred. Each of the two three-phase 60-cycle 650-volt, delta-connected main alternators is designed to deliver 625 kw. when running at 3600 revs. per min. The design does not materially differ from standard English practise, the rotors being solid steel forgings with milled slots, which take form-wound coils. Gun-metal wedges hold the coils in place and special caps of the same material secure the end windings from displacement by the heavy centrifugal forces. Provision has been made for exciting one or both alternators from the ship's 20-kw. 60-volt d-c. lighting dynamo,

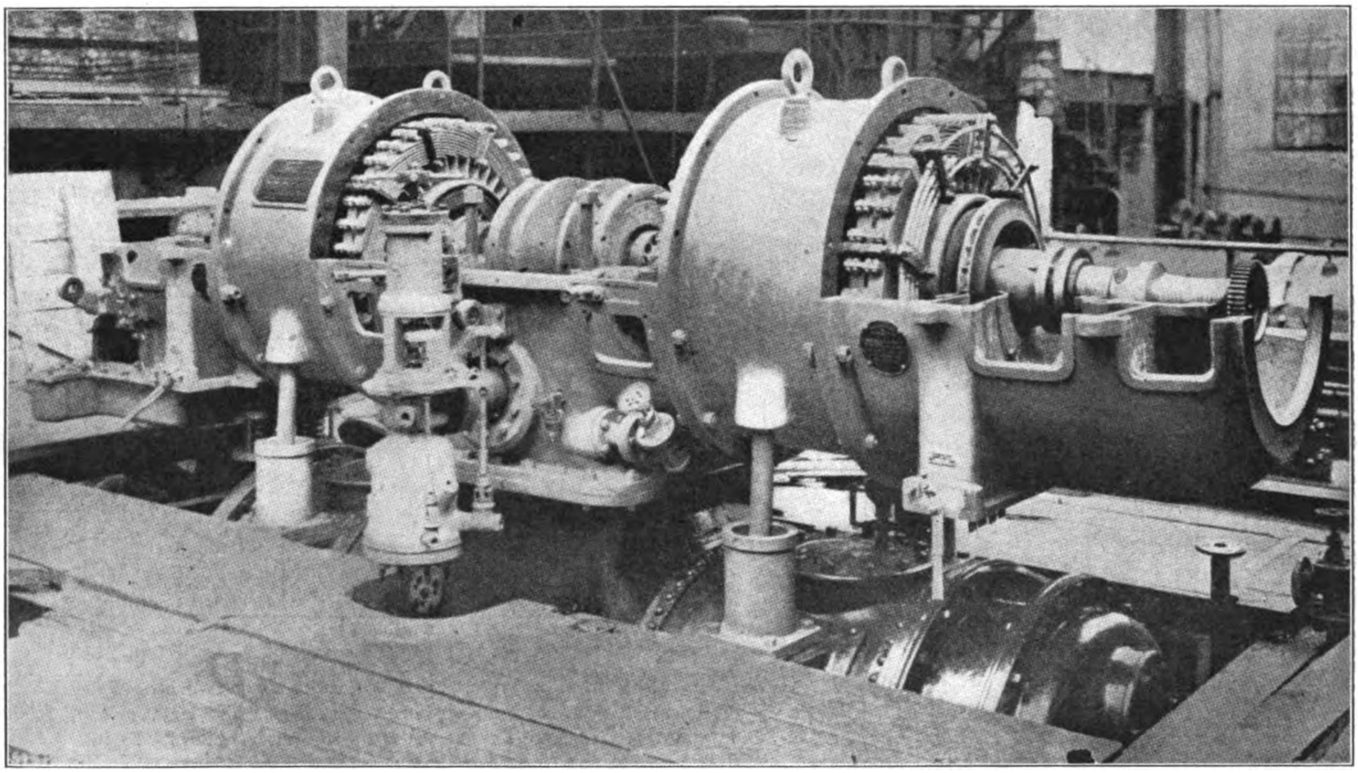


FIG. 3—LJUNGSTROM TURBO ALTERNATOR IN COURSE OF ERECTION

Fig. 4 shows the complete turbine lifted clear of the exhaust casing with the blading intermeshed and clamped in position. The special lifting gear shown allows the turbine to be rotated on one or both of two axes, thus facilitating inspection and handling. Each turbine has 39 rings of which 20 are on one disk and 19 on the other. The external diameter is 28 in. (711 mm.) and the overall length is 17½ in. (440 mm.), the total weight being only four cwt. (448 pounds). The kinetic plant is mounted near the turbo alternator and the three pumps necessary for its operation are mounted on one vertical motor-driven shaft.

Alternators. From the foregoing it will be clearly seen that each turbine runs two separate alternators. These two alternators are permanently connected in parallel, with their fields in series, and are invariably regarded as one unit. As the turbine runs up to speed

should the necessity at any time arise. This dynamo is so arranged that it can be either driven by a motor at sea, or by a small De Laval turbine in port, and is capable of exciting one or both alternators, in addition to meeting the ships lighting requirements and operating the ½-kw. standard Marconi wireless plant.

Main Motors. The two main induction motors are of the wound-rotor type and are fitted with the usual design of brush lifting and short-circuiting gear. Each is designed for a speed of 714 revs. per min. and rated at 785 h.p. Trial tests indicate an efficiency of 95 per cent and a power factor of 0.875 at full load. These motors run in pedestal-type bearings with split spherical bushings. They are arranged for forced lubrication, and each is ventilated by its own fan mounted on the rotor spider. The stator windings are arranged with a single bar per slot and insulated with seamless

mica tube, the end connections being heavy copper strips. The rotor windings are of the cylindrical barrel type as shown in Fig. 5.

Gearing. The gearing is illustrated in Figs. 7 and 8. The pinions are 9.2 in. (233 mm.) in diameter at the pitch line and have 23 teeth. The large wheel with which they gear is 86 in. (2.18 m.) in diameter and the reduction ratio is 9.4 to 1. The total effective width of face is 22 in. (558.8 mm.). The thrust block is of the Mitchell type and is incorporated in the gear case. Two gear-driven oil pumps are mounted at the ends of the pinion shafts, and supply all the bearings including those of the main motors.

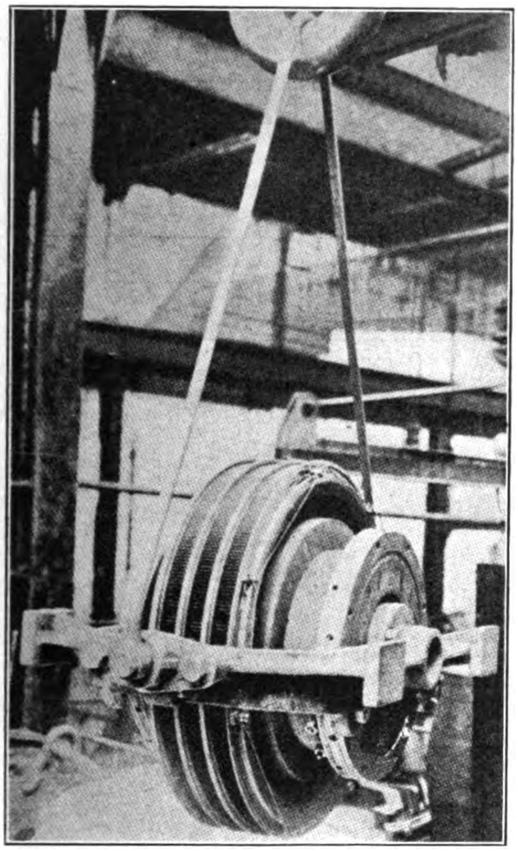


FIG. 4—COMPLETE TURBINE LIFTED CLEAR OF CASING

Switchboard. The switchboard represents standard shore practise. An ammeter, and a hand-operated oil switch, fitted with the usual overload and time-lag arrangements are provided for each alternator and main motor. The wattmeters, exciter voltmeters and field regulators, synchronizing gear, etc. are all of the usual commercial types. The reverse current relay shown in Fig. 10 has been removed.

Control. The turbines are never throttled for the purpose of reducing the speed of the ship. Speed is controlled by manipulating variable resistances in the main motor rotor circuits, a small control hand wheel being used for this purpose.

Reversal is effected by reversing two phases in the main motor stator circuits by means of the control wheel and an automatic reversing oil switch. Orders from the bridge are transmitted by means of the engine room telegraph which is mounted at the control position in the forward end of the engine room. The electrodes used in the main motor rotor circuits are cone-shaped nickel castings, while the electrolyte is a solution of K O H. Two small circulating pumps circulate the electrolyte through specially constructed coolers. The cones are raised or lowered by means of the control wheel, to which they are geared. When the control wheel is in the stop position the tips of the cones are raised clear of the liquid thus breaking the rotor circuits of the main motors. A safety arrangement prevents the closing of the main motor switches until the control wheel is in the stop position, and also prevents the main motors being short-circuited unless the control wheel is in either the full speed ahead, or full speed astern, position.

Operation. Referring to Fig. 10, it will be observed that the first motion of the control wheel from the stop position in either direction closes the reversing switch for ahead or astern running as the case may be. The necessary direct current for operating the automatic reversing switch, it will be seen, is supplied, through a change-over switch, from either exciter. Further motion of the hand wheel (a) cuts out the operating coil of the reversing switch and closes the economy coil circuit (b) lowers the tips of the cones into the electrolyte and starts up the main motors (c) adjusts the shunt regulators of the alternator exciters to meet the changing load conditions (d) locks the main motor switches to prevent them being reclosed should they open with an overload, and finally (e) in the full speed position unlocks the main motor short-circuiting hand lever. The speed then, varies as the angle through which the control wheel has been turned from the stop position, 120 deg. representing full speed. From about 15 revs. per min. any speed can be obtained up to 76, a special locking arrangement enables the control wheel to be clamped in any desired position. A suitably adjusted counterbalance weight allows the control wheel to be turned freely. The time required to reverse the propeller from full speed ahead, to full speed astern or vice versa, is merely the time required to turn the hand wheel from one extreme position to the other, and is approximately 10 seconds. Considerable difficulty was at first experienced in bringing the motors up near enough to synchronous speed, to enable them to be safely short-circuited. To surmount this difficulty, a hand-operated non-inductive grid-type buffer resistance can be placed in parallel and operated in conjunction with the liquid controller when short-circuiting the rotor windings.

Load. In still water the load depends on the draught of the ship, and ranges from approximately 30 per cent when the ship is light to full load value when the ship is fully laden. At sea, the load depends on the position of the propeller in the water, and in bad weather, continually fluctuates from approximately 25 per cent to

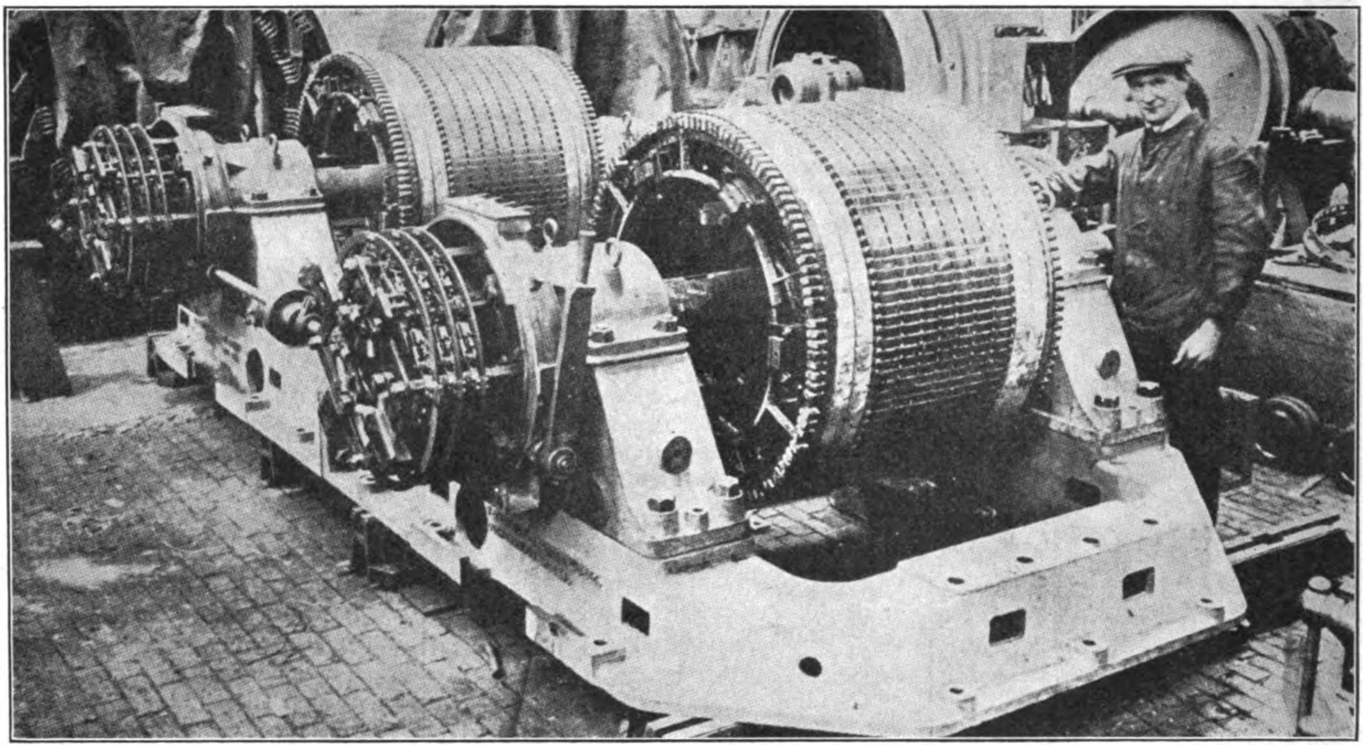


Fig. 5—Rotors of the Main Induction Motors

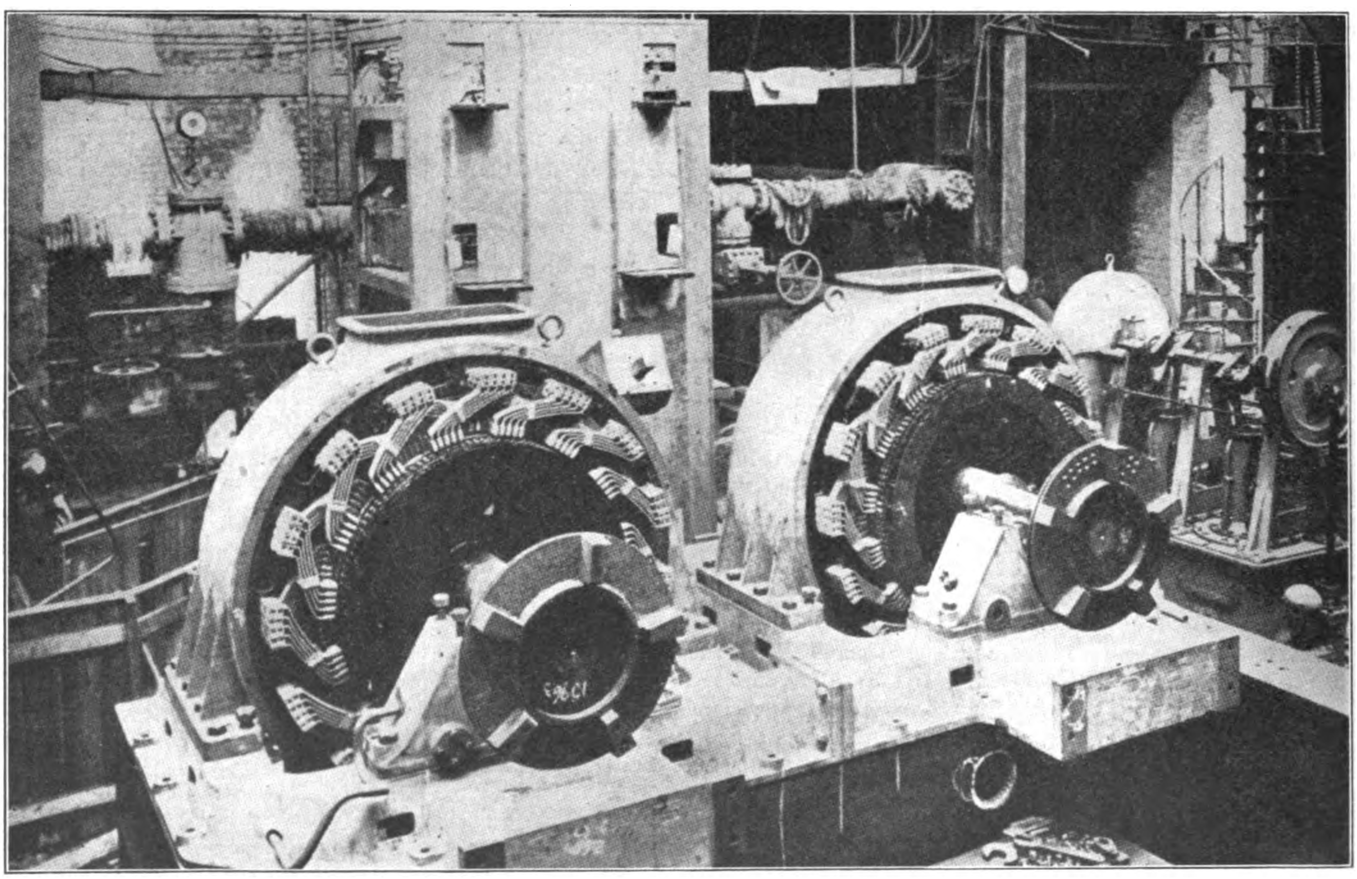


Fig. 6—Main Motors in Course of Erection

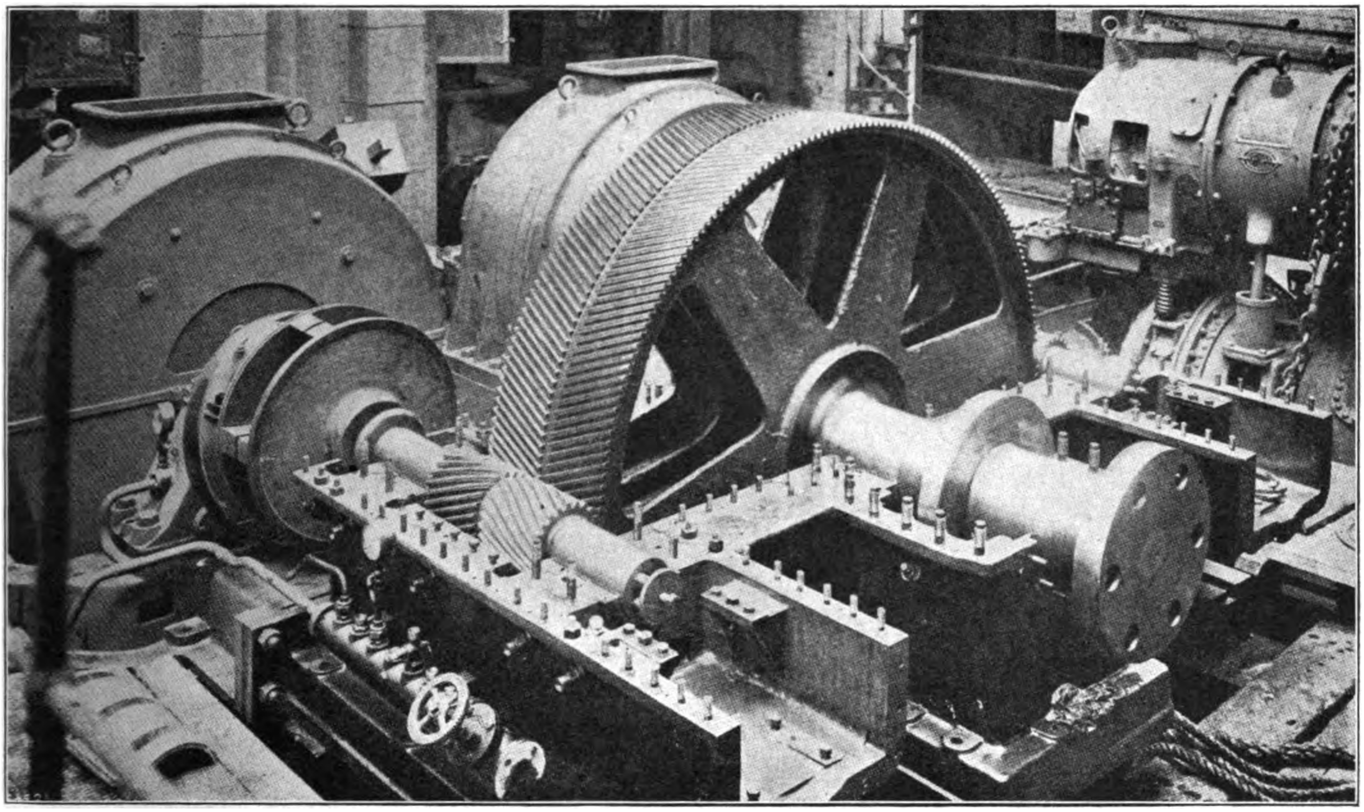


Fig. 7—Gearing with Cover Removed

150 per cent of full load normal value. Even in the heaviest seaway, with this drive, absolutely steady running is at all times assured, and "racing," which imposes very severe strains on other types of marine engines, is here quite unknown.

Auxiliary Motors. Practically all of the auxiliary machinery in this plant is motor-driven, three-phase squirrel cage motors of substantial construction being used. Two small switchboards, for the control of these motors, are mounted on the engineroom after bulkhead. Most of these motors are not equipped with starting devices, and are therefore usually run up with the alternators, in preference to switching them directly across full line voltage. Two 17-h.p. motors drive the main circulating pumps for the condensers at 1730 revs. per min. while two 14-h.p motors operate the combined kinetic, head and pressure pumps at the same speed. The 20-h.p. boiler feed pump motor runs at

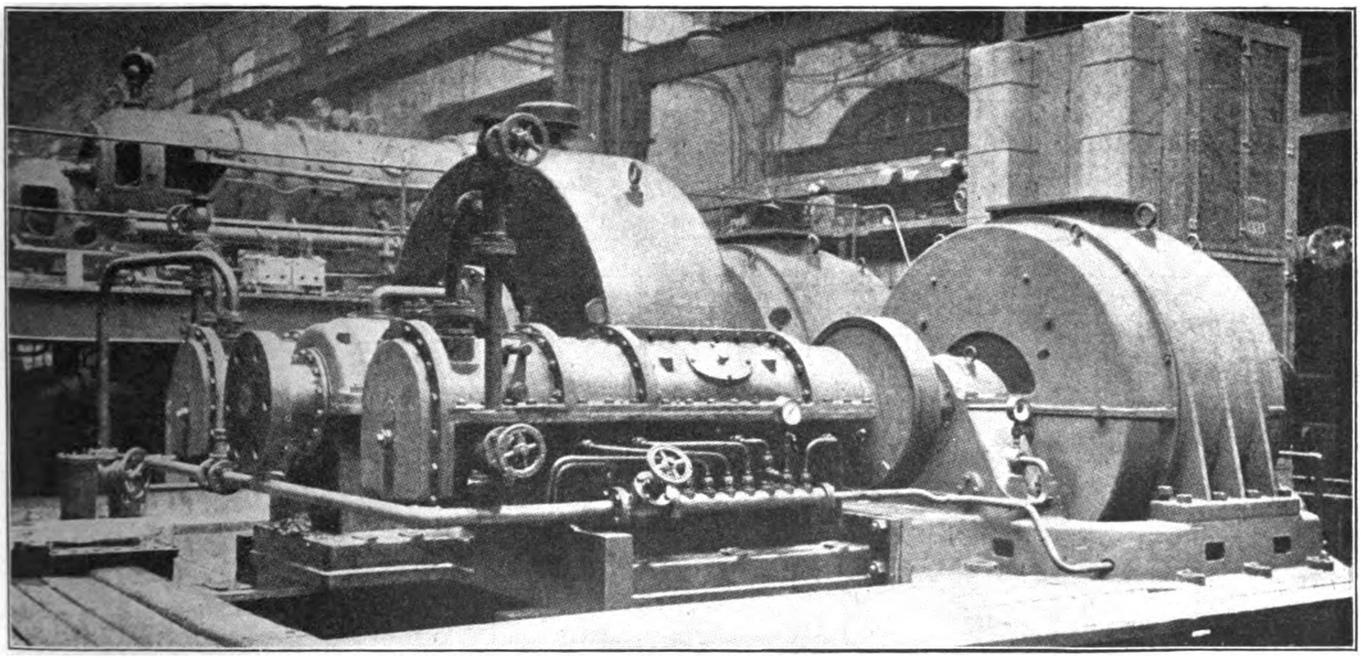


Fig. 8—General View of Main Motors and Gearing

3515 revs. and is equipped with a star-delta starting device.

Two small motors of 1½ h.p. each, circulate the

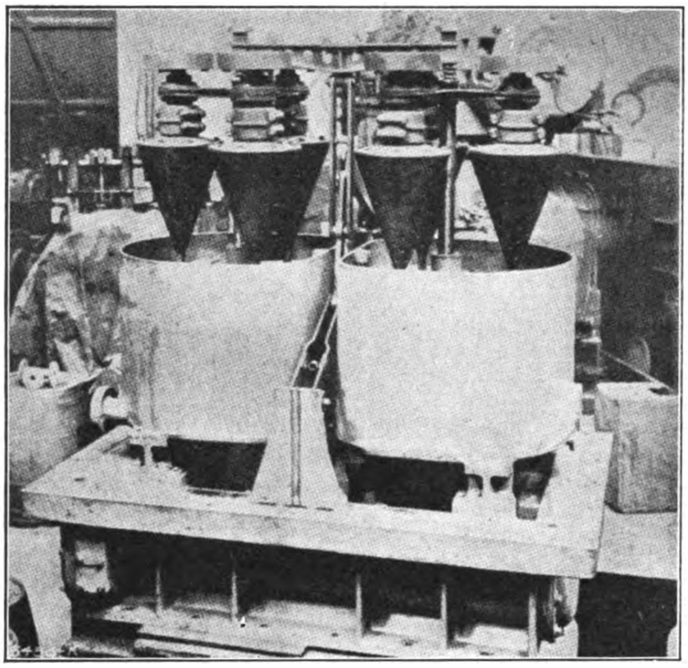


Fig. 9—Variable Liquid Resistance for Controller

electrolyte of the main motor controllers, through coolers of special design, and run at 1100 revs. A 33-h.p. motor, speed 1720 revs. and fitted with an auto-starter, drives the ship's lighting dynamo while at sea, and a 700-rev. per min. 12-h.p. motor, fitted with a star-delta starter operates the ships steering gear. This last motor normally runs light, and is only loaded when the steering wheel on the bridge is moved, this movement being transmitted to the steering compartment by means of telemotor gear. Although the above motors have often been called upon to operate under most unfavorable conditions, they have always furnished excellent continuous service at sea, and have conclusively demonstrated, that for this class of marine work, the squirrel cage motor of reliable make, requiring as it does the minimum of attention, and occupying a very small amount of space,—both important factors in a ship's engineroom—is eminently suitable.

General. Unfortunately no data of a reliable nature are available regarding the economical end, but the writer, judging from previous marine experience with other types of drive, is of the opinion that this is entirely satisfactory. Notwithstanding the severe operating conditions, practically no trouble has been experienced with the electrical end at sea, with the exception of that caused by the deterioration of rubber insulation due to excessive heat while in tropical latitudes. One breakdown, which necessitated the ship being run at reduced speed and efficiency by one alternator while the necessary repair was being affected, was occasioned by a badly sweated alternator rotor slip ring connection generating sufficient heat to loose its solder leaving a loose connection held together by a

GENERAL PARTICULARS OF SIX HOURS FULL POWER TRIAL WITH SHIP MOORED AT QUAY, AT SUNDERLAND, ENG.

Wednesday, July 3rd, 1918.

Time p.m.	Revs. per min.		Volts.	Port turbine.				Starboard turbine.				Temp. of sea Deg. F.	Kilowatts.		
					Before valve.		Vacuum by Kenoto-meter.		Before valve.		Vacuum by Kenoto-meter.				
	Turbine.	Propeller shaft.		Amperes	Pressure.	Temp. deg. F.		Amperes	Pressure.	Temp. deg. F.			Port.	Star-board.	Total.
1.30	Synchronized both turbines.														
2.0	3,600	75	660	700	190	555	28.9	600	190	560	28.7	58	696	595	1,291
3.0	3,600	75	660	700	190	582	28.9	600	190	590	28.7	58	696	595	1,291
4.0	3,600	74	650	700	190	578	28.9	600	210	590	28.7	58	687	589	1,276
5.0	3,550	75	630	680	210	579	28.9	670	210	580	28.7	58	645	638	1,283
6.0	3,550	74	630	630	200	581	28.9	700	200	574	28.7	58	600	660	1,266
7.0	3,550	74	650	650	195	589	28.9	680	200	580	28.7	58	646	665	1,311
8.0	3,525	75	630	630	195	588	28.9	685	195	585	28.7	58	600	652	1,252
9.30	Shut down.														
Means	3,568	74.5	644	670	195	579	28.9	648	199	580	28.7	58	653	628	1,281

Designed normal full load output of both turbines		1,250 kw.
Actual output of both turbines on trial		1,281 "
Power used by auxiliaries as measured on trial:		
Two circulating pumps	27.4 kw.	
Two air or kinetic pumps	27.0 "	
One boiler feed pump	15.2 "	
Electrical steering gear	6.2 "	
Lighting circuits	4.2 "	
Total for auxiliaries	80.0 kw.	80 "
		1,201 kw.
Less energy absorbed in motors of 95 per cent efficiency	60.0 kw.	
Less energy absorbed in gearing of 98 per cent efficiency	24.0 "	
	84.0 kw.	84 "
Balance or net power on propeller shaft		1,117 kw.

1,117 kw. equals 1,117 ÷ 0.746 or 1,496 S.H.P.

single rivet; the consequent arcing at this point ultimately opening the circuit.

The electric ship propulsion porposition has much to recommend it, and this phase of electrical advancement undoubtedly offers a wide field for future investigation and development.

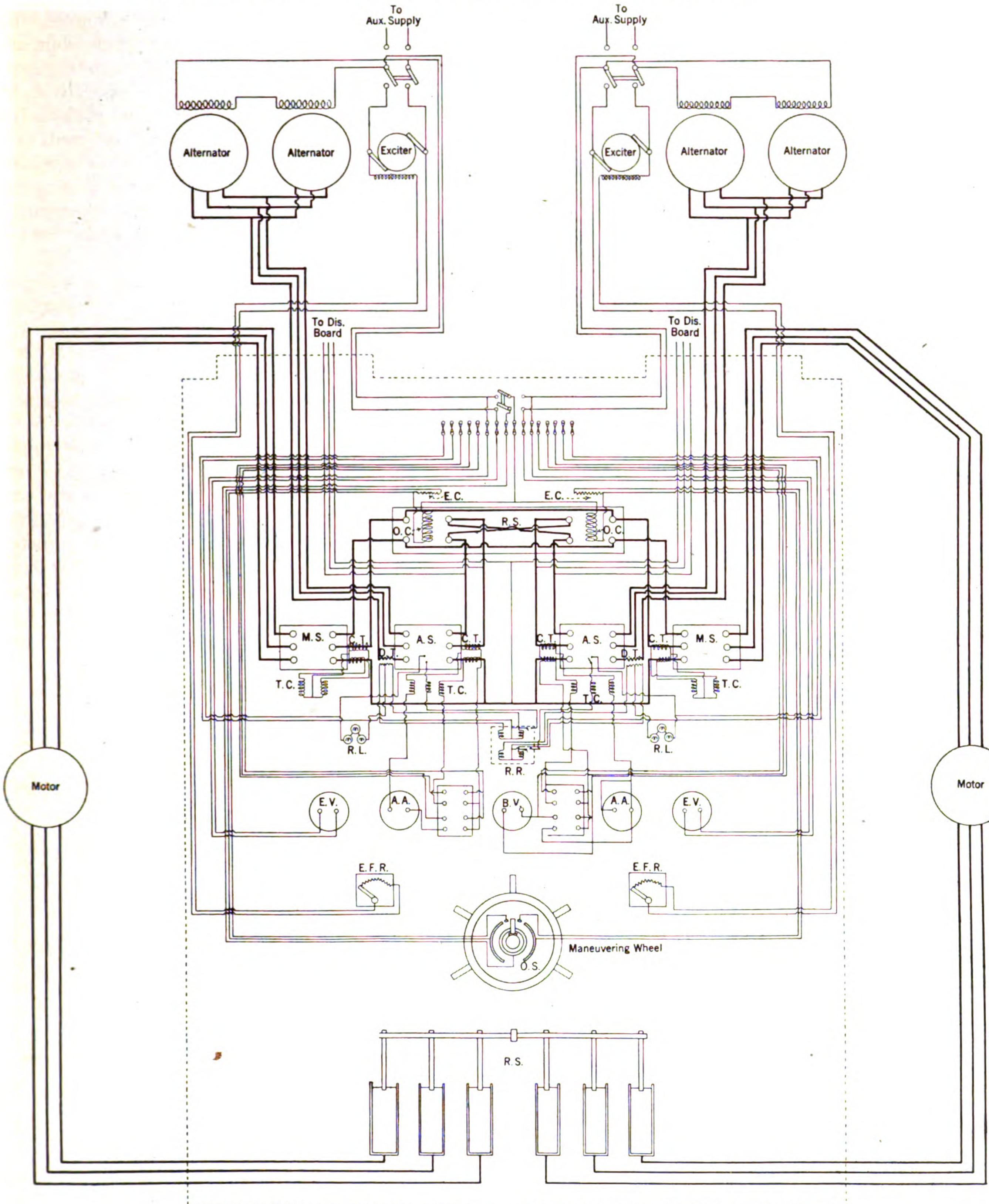


Fig. 10—Diagrammatic Sketch of Electrical Connections

ndex

A. S.	Alternator Oil Switch	*T. C.*	Oil Switch Trip Coils	*E. V.*	Exciter Voltmeter
M. S.	Main Motor Switch	*D. T.*	Transformer for Reverse Gear	*A. A.*	Alternator Ammeter
R. S.	Reversing Switch, Elec. Operated	*R. R.*	Reverse Relay	*O. S.*	Operating Switch for Main Rev
O. C.	Operating Coil for Switch	*R. L.*	Lamps (Pilot Lights) used as Resistance in Reverse	*E. F. R.*	Exciter Field Regulator
E. C.	Economy Resistance(inserted when core is up)			*R. S.*	Liquid Rotor Starter
C. T.	Current Transformer	*B. V.*	Bus Bar Voltmeter	*I. W.*	Integrating Wattmeter

Electric Propelling Machinery for U. S. S. Tennessee

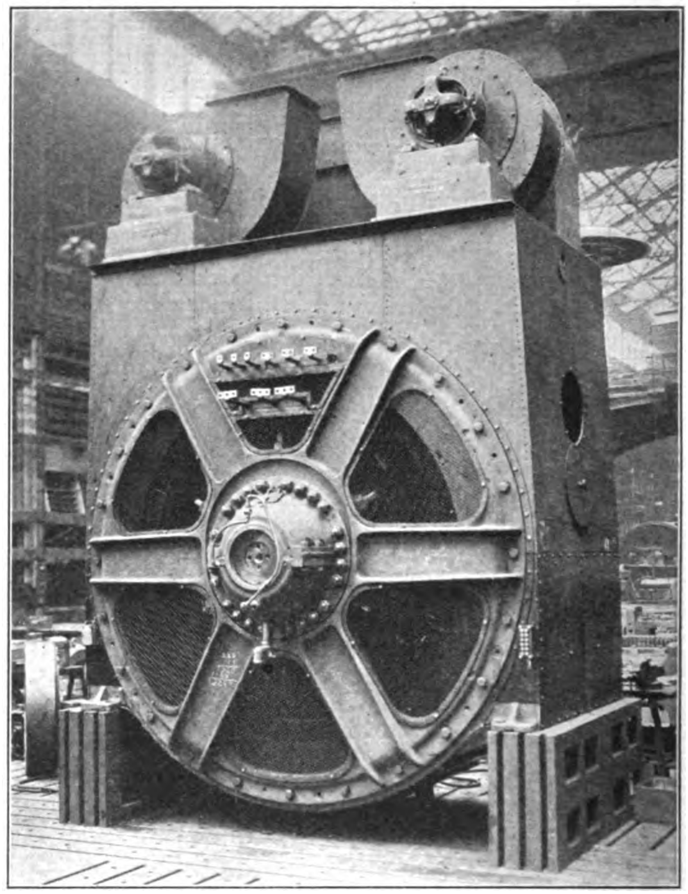
BY WILFRED SYKES

General Engineer, Westinghouse Electric & Mfg. Co.

THE U. S. S. *Tennessee*, which is now rapidly approaching completion, will be the second battleship to be equipped with electric propulsive machinery. The *New Mexico*, which was placed in operation about a year ago, has demonstrated the success of this system of propulsion. The U. S. S. *Tennessee* differs in a number of respects from the U. S. S. *New Mexico*, mainly in connection with the layout of the machinery and the details of the electrical apparatus installed. The *New Mexico* was originally designed for direct-connected turbines and was adapted to electric drive with minor structural changes. Full advantage was not taken, therefore, of the characteristics of electrical drive which allow of the apparatus to be disposed in the most suitable manner. In the case of the U. S. S. *Tennessee* full advantage has been taken of the flexibility in the arrangement of the electrical machinery, and therefore this ship will be the first which will illustrate completely what can be done with electric drive.

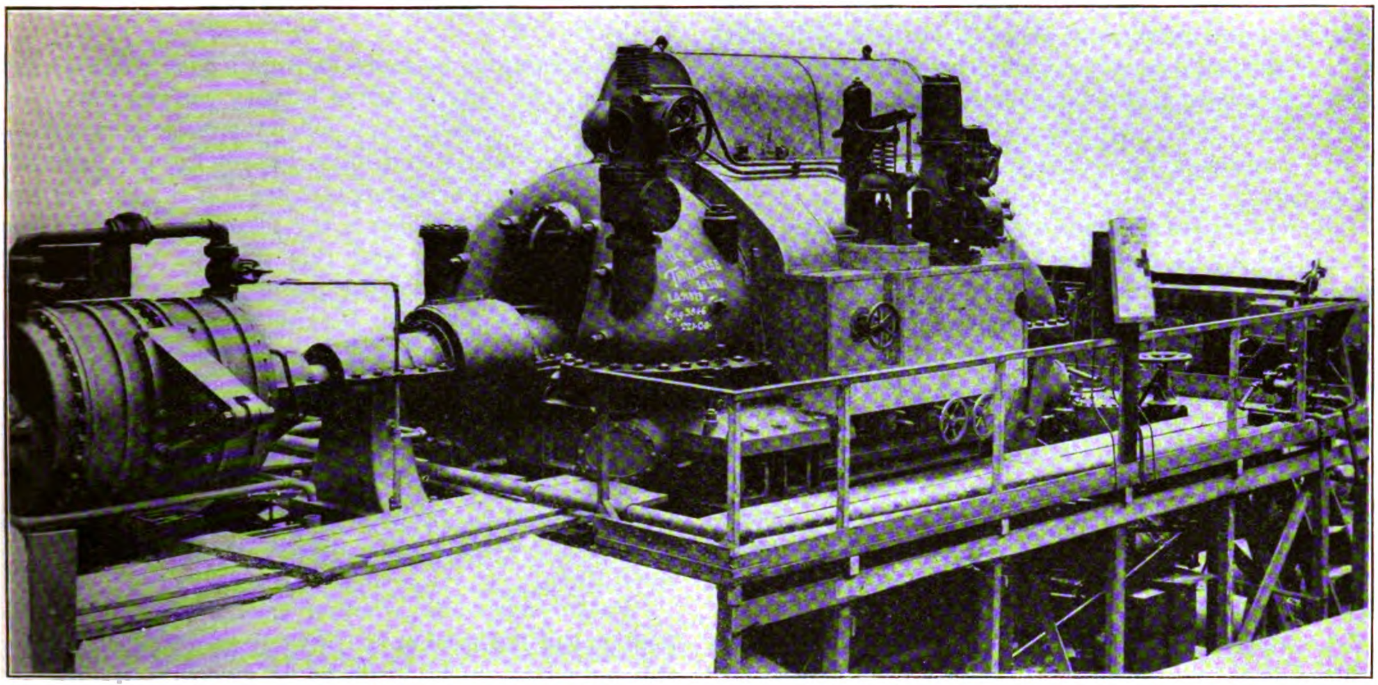
Various claims have been made for electric drive, basing its superiority upon questions of economy, maneuvering capacity and such characteristics. It is believed, however, that the greatest advantage of electric drive for battleships is the ease with which it can be arranged to give the greatest protection to the machinery and the best construction of ship. It can be stated without exaggeration that the use of electric drive would be justified from this standpoint if in other respects it did not compare with what had been previously used, as it is of fundamental importance that the machinery shall be reliable and protected in such a manner as to be as free as possible from injury when in action. The protection given the machinery in the case of the U. S. S. *Tennessee* by means of numerous bulk heads, is very much superior to anything done before in ships of this class, so that it is practically impossible to put the machinery out of operation either by gunfire or by torpedo attack.

The propelling machinery for the U. S. S. *Tennessee* consists of two turbo generators and four propelling motors. The switching apparatus is so arranged that either generator can drive all four motors, or that the two generators in operation each will drive two motors. The motors are grouped in pairs on either side of the ship so as to facilitate maneuvering. The turbo generators have a combined capacity of about 26,500 kw., which will be required to drive the motors when operating under the maximum conditions, each motor then delivering 8375 h.p. The speed of the motors is varied by varying the revolutions of the turbine within certain limits, and the motors also have two sets of poles, so that with the turbine running at full speed there is a speed reduction of about 12 to 1 and 18 to 1 to the propellers. With the motors running at the lower speed only one generator is used, and a speed up to 15 knots is obtained under this condition. As ships of this type operate mainly at speeds of 15 knots or less, the average operating economy is very greatly improved by the possibility of so dividing the power equipment that the best efficiency can be obtained at full speed or about ¾ speed.



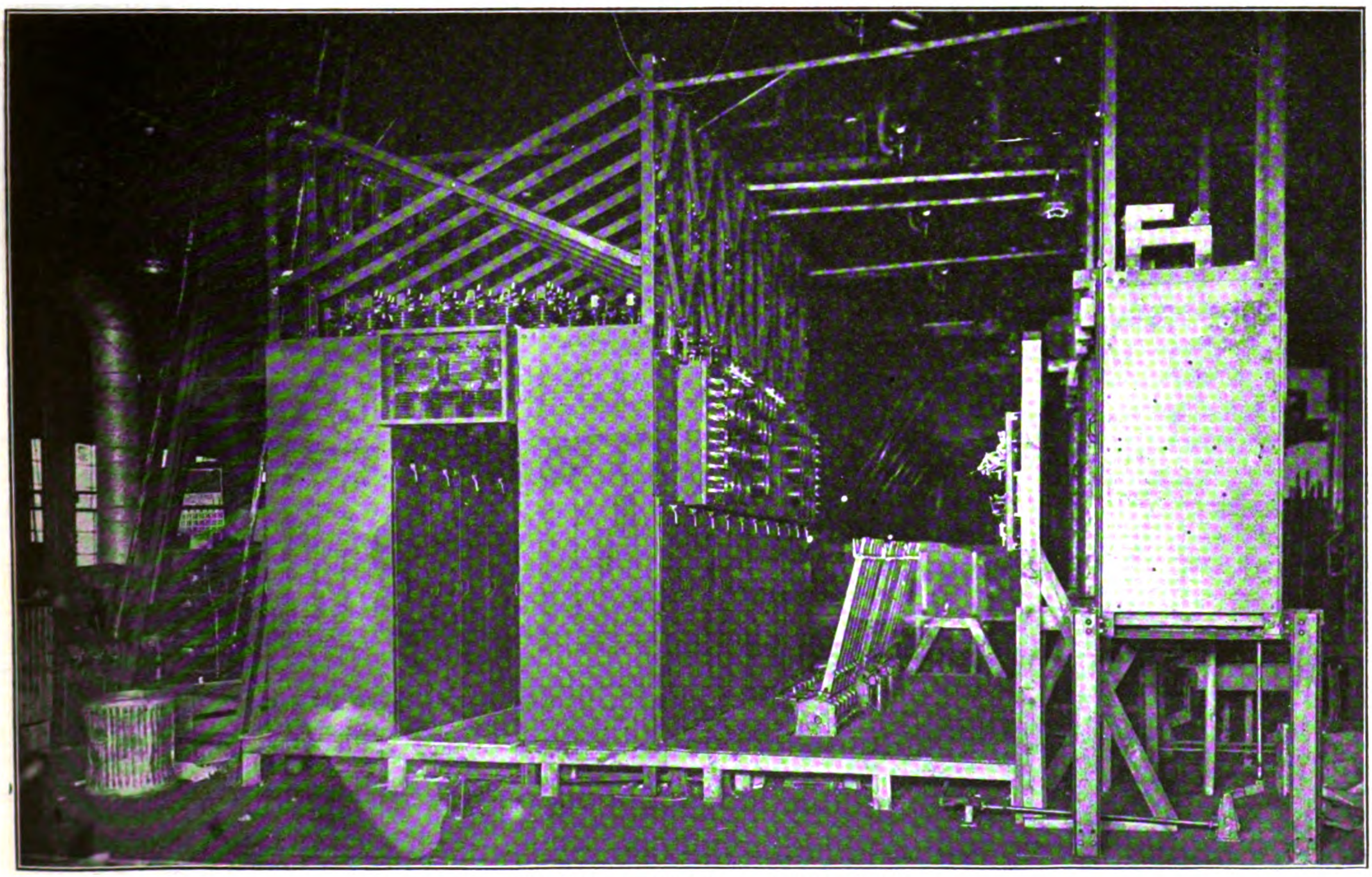
MAIN PROPELLING MOTOR WITH BLOWERS ASSEMBLED IN FACTORY

The turbines are designed to operate with a steam pressure of 250 lb. per sq. in., 50 deg. superheat and with a vacuum of about 28 ½ in. They are of the semi-double-flow type, steam being first expanded in suitable nozzles and flowing through an impulse wheel with two rows of blades. It then expands further through a set of reaction blading until the volume of steam is such as to render it inconvenient to handle, when it is divided and flows through two sets of reaction blading at either end of the turbine. The turbine speed under normal operating conditions is about 2130 rev. per min. maximum, and on test the machine has been run to 2480 rev. per min. The speed of the turbine is varied by means of a specially designed



Main Turbine on Test Floor Coupled to Water Brake

governor which, instead of being loaded by a spring as is usual, is arranged so that the centrifugal weights act against an oil pressure on one side of a piston. With such an arrangement the speed at which the governor will affect the steam supply will vary with the oil pressure, and by varying this pressure, the turbine can be set to run at any speed desired. A specially designed variable pressure valve is provided in the control room, for the purpose of operating the governors, and the only connection between the control room where the speed is varied and the turbine room is an oil pipe connecting to the governor piston.



Control Equipment Assembled in Factory

The generator is a three-phase machine wound for 3400 volts and operates at about 35 cycles at full speed. It is of the usual construction for machines of this size, except that special provisions have been made to avoid salt deposits in the windings. This is a trouble which is likely to occur where machines are operated in salt laden air.

The motors are designed with two sets of poles, being connected for 24 poles for full speed and for 36 poles for cruising. The stator has two separate windings and the rotor has a single winding which is so arranged that it is a polar winding for 24 poles and a short circuit winding for 36 poles. The winding has cross connections arranged in such a manner that they act as equalizer connections for 24-pole connection of the stator, and as short circuiting connections for the 36-pole connection. The motor is started as a wound-rotor machine by means of a liquid rheostat, and in case it is desired to run on 36-pole connection the machine is switched over to this pole connection.

The operation of the ship is controlled by the switching regulating apparatus in the control room. Cables from the generators are brought into this room, passing through the necessary switches to the motors. The secondary leads from the motors are also brought through liquid rheostats which are located in the control room. All necessary instruments for the operation of the equipment and the measurement of the power are located in this room, and the necessary telegraphs and other communicating devices are suitably located so as to facilitate communication with the navigating officers. All switching is done by means of oil immersed switches, and while normally circuits will be broken with the field of the generator disconnected, the switches are of such construction that they can be operated under full power. The variable pressure valves for operating the turbine governors are located in this room, as well as the rheostats for varying the field of generators.

The field of generators is controlled through a machine which is arranged to buck or boost the 240-volt direct-current power circuit of the ship. This booster is motor driven and the exciting voltage is varied through the booster field which is reversible.

The guarantees for this ship based on 250 lb. steam pressure, 60 deg. circulating water with no superheat are as follows:

21 knots	....	11.9 lb.
19 "	....	11.65 "
15 "	....	12.1 "
10 "	....	15.45 "

These figures include all the power required for driving the circulating pumps, condensate pumps, ventilating blowers for machines and excitation.

PRODUCE AND SAVE

It is coming to be more and more widely recognized that the only effective remedy for the abnormal economic conditions which have resulted in successively higher prices and higher wages lies in increasing production and increasing savings. Produce all you can and save all you can is the solution of the present economic difficulties, and this thought is admirably expressed in the following paragraphs by Albert W. Atwood in the *Saturday Evening Post:*

"The only way to break the vicious circle is by the slow, painful process of work and save throughout the world. In time, Europe will be able to supply her own needs. In time, the supply of goods will catch up with demand, and then we shall have gradual deflation in place of inflation, because it will be possible slowly to pay off the world's debts and the bank credits based upon them.

"Patent nostrums, whether they apply to business men on the one hand or to the wage earner on the other, will only lead up blind alleys. Improved machinery, more scientific devices, better organization of industry, more economic distribution of its products, better training of the worker, more democracy in industry and more good will between capital and labor—all these will help. But they take years, generations perhaps, to bring about, and patent schemes to rush them into being are pitifully futile.

"And as for working and saving, the bitter truth is that this doctrine will prove our salvation only if people learn that it applies to themselves as well as to the other fellow."

PLANS FOR DISABLED SOLDIERS

It is announced that the War Department, Federal Board for Vocational Education, and Civil Service Commission will within a few weeks have completed a plan they have had under consideration for some time, one of cooperation whereby the employment under the War Department of partially disabled soldiers, including those who ordinarily would be barred from civil positions because of their physical condition, will be facilitated in every way possible, and which will permit the employment of partially disabled men on same basis as those who have not sustained physical injury. War Department has considerably more than 100,000 civilian employees in its various establishments, and it is believed by Government officials that this large force can absorb several thousand partially disabled men without serious detriment to the service.

The Expression of Dielectric Losses in Cables

BY WM. A. DEL MAR

Chief Engineer, Habirshaw Electric Cable Co.

Dielectric losses in cables depend upon the characteristics of the current, the dimensions of the cable and the specific qualities of the insulation. In order to compare the specific qualities of different insulations with respect to dielectric losses, it is desirable to find a method of expressing these specific qualities independently of current characteristics and cable dimensions. This will permit different insulations to be compared even when tests are made at different voltages, or on cables of different sizes. A method of attaining this result is here suggested.

The method consists in expressing the specific quality of the insulation with respect to dielectric losses, in terms of the product of its power-factor and specific inductive capacity. This may be termed the coefficient of dielectric loss and is hereinafter designated by the letter K_L.

If the specific inductive capacity or specific capacitance may be considered to have a maximum value of 3.5 for impregnated paper insulation, the coefficient of dielectric loss must be between zero and 3.5, the value zero corresponding to zero power factor or perfect insulation, and the value 3.5, to unity power factor or the worst insulation. Hence the lower the value of K_L, the better the insulation from the point of view of dielectric losses. The following values are characteristic of different makes of insulation.

VALUES OF K_L

Temperature deg. cent.	Cable No.					
	I	II	III	IV	V	VI
50	0.093	0.12	0.30	0.22	0.31	0.31
70	0.32	0.43	0.55	0.65	0.78	0.90
90	0.67	0.89	1.57	1.59	1.68	1.80
110	1.13	1.51	2.98	2.93	2.96	2.93

It is proposed for specification purposes, that the Institute standard maximum temperature be adopted, and that, unless otherwise stated, K_L shall refer to that temperature, which is given as 85 deg. cent. for paper in the 1918 Standardization Rules.[1]

The coefficient of dielectric loss may be derived as follows from single-phase measurements of dielectric loss on a triplex cable.

Fig. 1 shows a diagrammatic representation of the capacities in a triplex cable.

Let I = charging current in line, per mile of cable

I_c = charging current per mile from one conductor to *each* other conductor

I_s = charging current per mile from each conductor to sheath

E = kilovolts between conductors

C_c = microfarads per mile one conductor to another

C_s = microfarads per mile one conductor to sheath

Then $I = \sqrt{3}\, I_c + I_0$

$I_c = 2\,\pi f E\, C_c$ in milli-amperes

$I_s = 2\,\pi f\ E/3\ C_s$ in milli-amperes

$$I = 2\,\pi\,\sqrt{3} f E\,(C_c + C_s/3) \qquad (1)$$

Let w = dielectric loss, watts per mile of cable

θ = power factor angle

Then

$$w = \sqrt{3}\, E\, I \cos\theta \qquad (2)$$

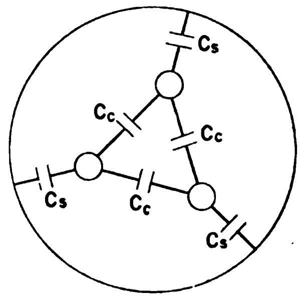


Fig. 1

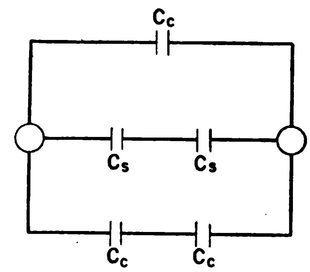


Fig. 2

Combining equations **1** and **2**

$$w = 2\,\pi f E^2 \cos\theta\,(3\,C_c + C_s) \qquad (3)$$

Now C_c and C_s are purely mathematical conceptions not susceptible of direct measurement. They are the capacities of imaginary condensers. The real capacities differ due to being composed of groups of these imaginary capacities in series or parallel. We must therefore reduce these imaginary capacities to real capacities.

Let C_1 = actual capacity (as measured) between any two conductors, the third being insulated.

Then C_1 is composed of the combination of C_s and C_c shown in Fig. 2.

$$C_1 = 1\tfrac{1}{2}\,C_c + \tfrac{1}{2}\,C_s$$

$$= \tfrac{1}{2}\,(3\,C_c + C_s)$$

or

$$(3\,C_c + C_s) = 2\,C_1 \qquad (4)$$

Combining equations (3) and (4)

$$w = 4\,\pi f E^2 \cos\theta \,.\, C_1 \qquad (5)$$

Let k = specific capacitance

and $C = C_1/k$

Then

$$w = 4\,\pi f E^2 \cos\theta \,.\, k \,.\, C$$

Let $K_L = k\cos\theta$

Then,

$$w = 4\,\pi f E^2 K_L\, C \qquad (6)$$

1. Rule 677 of the 1918 Standardization Rules says that the maximum safe temperature, in degrees cent., at the surface of the conductor shall be 85—E, where E represents the r. m. s. operating e. m. f. in kilovolts between conductors. It is proposed to make 85 deg. cent. the temperature of reference whatever the voltage of the cable.

Let W = watts lost per foot of cable
Then

$$W = \frac{4\pi}{5280} f E^2 K_L C$$

$$= 0.00238 f E^2 K_L C \qquad (7)$$

$$\text{or } K_L = \frac{420\, w}{f E^2 C} \qquad (8)$$

The coefficient C, depending only upon the size and shape of conductor and upon the thickness of insulation may be derived either from a general table such as Table II or calculated from a formula such as the one which follows:

$$C = \frac{0.01945}{A} \qquad (9)$$

Then $i = \sqrt{3}\, i_c + i_s$

$$i_c = E/R_c$$

$$i_s = \frac{E}{\sqrt{3}\, R_s}$$

$$\text{Therefore } i = E/\sqrt{3}\,(3/R_c + i/R_s) \qquad (10)$$

These resistances are purely imaginary conceptions. Let R be the actual resistance from one conductor to another, the other conductor and sheath not being in circuit. All resistances are expressed in ohm-miles.

Then

$$R = \frac{2}{(3/R_c + 1/R_s)}$$

$$\text{or } (3/R_c + 1/R_s) = 2/R$$

$$\therefore i = 2/\sqrt{3} \times E/R$$

TABLE II

VALUES OF C

Actual Capacity of Triplex Cable as measured between any two conductors, the third being insulated (Sp. Cap. = 1). Microfarads per mile.

Size, Cir. Mils or A. W. G.	Thickness of Insulation on each conductor and Belt, 64ths Inch.															
	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22
500,000	0.128	0.113	0.101	0.092	0.085	0.079	0.073	0.070	0.066	0.063	0.061	0.058	0.054	0.050	0.048	0.046
450,000	0.123	0.108	0.098	0.088	0.082	0.076	0.073	0.067	0.064	0.062	0.059	0.057	0.053	0.049	0.047	0.044
400,000	0.121	0.104	0.094	0.086	0.080	0.074	0.070	0.065	0.063	0.060	0.057	0.054	0.051	0.048	0.045	0.043
350,000	0.118	0.103	0.092	0.083	0.076	0.071	0.067	0.063	0.060	0.058	0.056	0.053	0.049	0.046	0.043	0.041
300,000	0.112	0.100	0.089	0.080	0.074	0.069	0.065	0.061	0.058	0.055	0.053	0.051	0.047	0.044	0.042	0.040
250,000	0.109	0.094	0.085	0.077	0.071	0.065	0.063	0.059	0.057	0.052	0.050	0.048	0.045	0.042	0.040	0.038
0000	0.104	0.091	0.080	0.073	0.068	0.063	0.059	0.055	0.053	0.050	0.048	0.046	0.043	0.040	0.038	0.036
000	0.097	0.086	0.075	0.068	0.063	0.059	0.055	0.052	0.049	0.047	0.045	0.043	0.040	0.038	0.036	0.034
00	0.093	0.080	0.071	0.065	0.059	0.055	0.052	0.048	0.046	0.044	0.043	0.041	0.038	0.036	0.034	0.032
0	0.088	0.075	0.066	0.060	0.056	0.051	0.049	0.045	0.043	0.041	0.040	0.038	0.036	0.034	0.032	0.030
1	0.083	0.071	0.063	0.057	0.052	0.049	0.045	0.043	0.041	0.039	0.038	0.036	0.034	0.032	0.031	0.029
2	0.075	0.066	0.058	0.053	0.049	0.046	0.043	0.040	0.038	0.037	0.035	0.034	0.032	0.030	0.029	0.027
3	0.072	0.062	0.055	0.049	0.046	0.043	0.040	0.038	0.036	0.035	0.033	0.032	0.031	0.029	0.027	0.026
4	0.068	0.058	0.051	0.047	0.043	0.040	0.038	0.036	0.034	0.033	0.031	0.030	0.029	0.027	0.026	0.025
6	0.060	0.052	0.046	0.041	0.038	0.036	0.033	0.032	0.031	0.029	0.028	0.027	0.025	0.024	0.023	0.022

$$\text{where } A = \log_{10}\left[\frac{d}{a}\;\frac{b^2 - d^2}{\sqrt{b^4 + b^2 d^2 + d^4}}\right]$$

in which a = radius of conductor, cm.
b = inside radius of sheath, cm.
d = distance between centers of conductors.

The above calculations are based upon the assumption that the ohmic losses are so low that it is not necessary to take into account the fact that they are independent of the frequency.

This may be easily shown.

Let i = amperes per mile of leakage current, per conductor
i_c = amperes per mile of leakage current from one conductor to another
i_s = amperes per mile of leakage current from one conductor to sheath
R_c = ohms per mile resistance, one conductor to another
R_s = ohms per mile resistance, one conductor to sheath

Let W_0 = watts lost in length having resistance R

$$= \sqrt{3}\, E \,.\, i\,.$$

$$= \frac{2\sqrt{3}}{\sqrt{3}}\,\frac{E^2}{R}$$

$$= 2\, E^2/R \qquad (11)$$

If E = kilovolts between conductors
R = megohm-miles
W = watts per foot, ohmic loss

$$W = \frac{2}{5280}\,\frac{E^2 \times 10^6}{R \times 10^6}$$

$$= \frac{1}{2640}\,\frac{E^2}{R} \qquad (12)$$

Suppose R = 10 and
E = 12

$W = \dfrac{10}{2640}$ = 0.0038 which is negligible in comparison with the loss due to the capacity current.

Pure Science and Industrial Research

BY J. J. CARTY
Vice-President, American Telephone & Telegraph Co.

IN MY address before the A. I. E. E. in 1916, to which Dr. Bumstead very kindly referred, I laid stress upon the importance of research conducted solely for the advancement of science. I testified to the great debt which applied scientists owed to the pure scientists, and I suggested that the industries owed an immense debt to science which they should pay by liberal contribution to those scientists, who, conducting experiments solely for the increase of knowledge, and without any expectation of pecuniary gain, give their services to this work. That paper was very well received, and I have been very much gratified to see how much good it has done to workers in pure science and among the physicists, particularly in gaining them recognition, for it appears that, as representing the American Institute of Electrical Engineers I had said something from the practical side which, if said by the theoretical or academic scientists, would not have had so much weight.

The address which has been referred to seemed to express the views of the National Research Council so well that it was published by that body as its first tract, and has had a wide circulation in this country, and abroad. The views which were set forth in the address have been very generally accepted, and to those who want to follow up this important line of thought, I suggest that they read that paper, if they have not done so; if they have done so, they might read it again, in the light of what I may have to say this evening.

The movement for research, particularly in the matter of pure science, has received a great impetus in this country. The National Research Council has been formed, and it has for its object the encouragement not only research in pure science, but also research in industrial science. As a result of its activities, there was a meeting called in London by The Royal Society which I attended as a delegate from the National Academy, at which the foundations were laid for an international research council.

At this meeting there were represented members from the Academy at Rome, the Royal Academy of Serbia, the Brussels Scientists, those from the French Academy, those from the Royal Society of England, and those from Brazil, in fact, representatives of all the Allies were present. These gentlemen were constituted the charter members of an International Research Council which later met at the rooms of the French Academy in France. All of this was an outgrowth of the war. The war brought the pure scientists and the applied scientists to the front. The work which they did in the laboratory and on the field of battle is a matter of history. It is work in which the members of both of our societies participated to a high degree.

Doctor Bumstead has very kindly referred to my testimony concerning the debt which applied science owes to pure science, and he has, in return, very generously acknowledged the debt which the pure scientists owe to the applied scientists. Now we are coming to a third situation, where we must consider the debt which civilization, as a whole, owes to science, both pure and applied, and the obligations which pure science and applied science assumes, and has assumed, to the public. Those who are engaged in work such as ours have undertaken immense obligations in behalf of the public, not fully realized by us, and very dimly perceived by the public.

The pure scientist furnishes to the engineer the raw material for his work. That is well illustrated, I think, in the telephone art. That art is founded primarily upon the work of the pure scientist and specifically upon the work of the physicist. When the telephone was invented, it was thought by studying the structure and operation of the human ear from the standpoint of the physiologist that we might find the solution of many problems in telephony, but a brief study showed that the answer was not to be found in that direction. We then turned our minds to the physicists, and at the very beginning our first advice and help came from the professors of physics in the universities. One of them, Prof. Cross was one of the very first advisers we had, and I am glad to say that he is still able to give us good advice.

When we consider the progress of the art of telephony, we will see that in the beginning it was difficult to speak even for a few miles. The charges for the telephone were considered to be excessive—they were so large that very few people could make use of it—but by following the pathways outlined by the pure scientist, studying his discoveries, and by the aid of the applied scientist, the improvement that has been made has been most remarkable.

During that period of forty years, you will find that wages, the cost of materials, and of living, were going up and up and up in an ascending curve. All of the fundamental factors which make the cost of telephony have been increasing. Wages have gone up, the hours of work have been lessened, the amount of air space per cubic foot allowed for employe has been increased, medical attendance has been provided, welfare work of all kinds has been arranged for, and in every way the comfort and health of the employe has been benefited—All these factors make for increased costs, but, notwithstanding all that, if you will look at the curve of the prices charged for telephone service you will find that they have been going down and down.

Abstract of an address before a joint meeting of the A. I. E. E. and the Am. Phys. Soc., Philadelphia, October 10, 1919.

Why is that? It has not been taken out of the inexhaustible treasury of the capitalists, because there is no such thing. Where has this come from. It has not been squeezed out of the flesh and blood of human beings. It has come from a more intelligent utilization of nature's forces—it has been squeezed out of old Dame Nature herself.

Now, there lies, I think, the great future for our organizations—the American Physical Society representing the pure scientist and the American Institute of Electrical Engineers, representing the applied scientist, —our great duty is to join hands in the conquest of the forces of nature.

We must realize that nature's resources are not limited to a fixed amount, so that if one gets something he must take it away from somebody else, but that outside of the boundaries of our present knowledge there is an unlimited store, and that we, instead of being engaged in a struggle of taking one from the other, should all be engaged in a struggle where we will all be working shoulder to shoulder in the struggle against the forces of Nature. We should believe that lying outside of the boundaries of our present knowledge, away off in the infinite, is a store of resources which it is your business, gentlemen, the pure scientists and applied scientists to discover and to mould into useful form for mankind.

I have spoken of the debt of the applied scientist to the pure scientist, and the debt of the pure scientist to the applied scientist. I now wish to say that both together, owe a debt to the public, and that both the pure and applied scientists have an obligation to the public to push forward the frontiers of our knowledge and occupy the newly discovered territory and to work all materials which are found therein for the benefit of mankind.

At present we are engaged in a very difficult situation growing out of the war. We have had many interferences with natural economic laws. Some were necessary and some unnecessary. The result is that we got into a sort of orgy of rising wages, in turn followed by increased prices, which, when the circle is complete, brings the workman right back where he was before, and the only remedy is to start off with another increase of wages, and that increase of wages followed inevitably by an increase in the price of commodities and the cost of living, and we are right back where we started. We are in a vicious circle. The conference at Washington is dealing with that vicious circle. All they can hope to do is to slow down the rate at which we are chasing ourselves around in that circle.

But we as scientists and engineers have another duty. It is our business to break through that circle, and I say, gentlemen, the only way out of this vicious economic circle is to send out the pure scientist to break through it, and to follow him up by the applied scientist. Once that idea gets into the public mind, once it gets solidly into our own minds, then we will look on our scientific work as an occupation of the highest kind, in which a man could engage.

I believe when the railroads are returned to their owners and affairs become more stabilized in this country, that we will have in connection with every great railroad, an important industrial research laboratory. All the great manufacturers, and all the manufacturers' associations realize the importance of industrial research, and are going to the colleges for men to conduct the laboratories. It is our business to educate the large industries to the fact that they must help to support the pure scientist; that they must regard him as though he were a discoverer of new mines which may contain vast riches for them, and that unless the pure scientist continues his discoveries, all fundamental progress will cease. Therefore, I think we must encourage corporations of all kinds, and individuals to contribute to the work of pure science, and justify it on the ground that it is a proper use of the funds of the corporation.

As time goes on, speaking in terms of the life of a nation rather than the life of a man, I believe that through the work of such societies as ours, that through the scientific discoveries which their members will make and apply, the working man, even the humblest, will enjoy comforts and advantages that are now undreamed of. These matters I am now discussing relate largely to material things and do not purport to solve those ultimate problems which are dealt with by philosophy and religion. While we cannot promise happiness to man, nevertheless I have faith that your scientific work, carried on for one hundred or two hundred years, or perhaps more, (a short time in the life of a nation) will place at the disposal of men such great material advantages that even the humblest will have the leisure and education and equipment to consider, as a man and not as a beast of burden, those higher problems of life and happiness which comprehend more than material things.

DECREASING TIMBER SUPPLY

The Forester of the Department of Agriculture states in Annual Report that the rate of depletion of forests of this country is more than twice, probably three times, what is actually being produced by growth in form serviceable for products other than firewood. Consequently, high prices of lumber are not wholly due to increased costs of production. An important factor is the ever-retreating sources of timber supply. Already the supplies of all the great eastern centers of production are approaching exhaustion, with exception of the South, and even there most of the mills have not over 10 to 15 years' supply of virgin timber. Already the southern pine is being withdrawn from many points as a competitive factor and its place taken by western timbers. This inevitably results in added freight charges, which the consumer must pay.

THE TECHNICAL STORY OF THE SYNCHRONOUS CONVERTER

[*Continued from page 26*]

It should be added also, that when the Westinghouse engineers added copper dampers to their laminated poles and thus stopped hunting, they discovered that difference in wave form was not controlling, in any sense, and they saw why the first General Electric converters, with their solid poles, apparently had hunted less than the Westinghouse, due to the damping currents in the poles themselves.

Of course, after the hunting trouble on 25-cycle converters had been practically eliminated by the dampers, there was no real necessity for following the "induction" type further, and that work was abandoned, except in one or two special instances. In 1894, the company had undertaken to build a 10-h. p., 60-cycle converter, which, however, did not prove at all successful in service, due to hunting. It was brought back to the shop for further investigation and experiment and it was determined that it would operate without any hunting whatever, with its field coils short-circuited on themselves, thus forming an induction converter. A new field was then constructed with very short poles and without any field winding and with a very small airgap, about the same as that of a small induction motor. This, at first, did not work as well as with the former field with the field coils short circuiting themselves. It was then assumed that the short circuited field coils must have had something to do with the operation and therefore on the new field, with small airgap, a heavy copper one-turn field winding was placed, short circuited on itself. With this winding, the operation was again quite satisfactory, and this machine was used for experimental purposes for many years. Its power factor was not as good as the excited-field type machine and the direct current delivered by it was slightly pulsating, so much so that it showed as a flicker on arc lamps when used for motion picture work.

Another type of "induction" converter was experimented with, about this time. In 1894 and 1895, the Westinghouse company, in putting up its new shops at East Pittsburgh, had adopted 25-cycles, two-phase for its power system. A number of converters of 125 and 250 volts were designed and built for delivering direct current for the testing rooms. These converters operated fairly well except that they hunted at times, the copper damper not yet being devised. This hunting led the writer to consider the use of one of these converters as a synchronous running machine without any field winding whatever. A set of circular punchings, of the same bore as the armature diameter, was slipped over the outside, making good magnetic contact with the outside of the armature core, and thus forming a completely closed magnetic circuit around the armature winding. This armature was then driven at synchronous speed by means of another machine, two-phase alternating current was supplied to the collector rings, and direct current was delivered at the commutator. This was practically the equivalent of the so-called "permutator" brought out in Europe some years later. This machine was not successful, due to the change in lead at the brushes with change in load. In fact, it was quite sensitive to brush setting and the d-c. voltage regulation was relatively poor. This machine was operated for several months in the testing room and was then dismantled.

The foregoing covers pretty well the development of the 25-cycle converter. By 1896, this type of machine was becoming fairly well established and by 1898, with improved dampers, began to be recognized as a thoroughly commercial machine. There were instances where even the 25-cycle converter gave trouble, which, in some cases, could not be explained away. Most of the converters at that time were operated from engine-type alternators and it was recognized, possibly somewhat dimly at first, that the generating conditions had something to do with converter troubles. It was recognized by a few engineers that where two generators would not operate satisfactorily in parallel, there was good reason to suppose that synchronous converters, operated from these machines, might not act very well either; but such cases were rare, for 25-cycle engine-type generators usually ran in parallel quite successfully.

Another condition, which came up in some of the earlier attempts, was high ohmic line drop. A few cases were encountered where very severe hunting developed, even in converters with fairly good dampers. Various investigations showed that increase in line voltage helped materially and it began to be recognized that an unduly large transmission drop was harmful for converters. The writer made an extended series of tests at one time to determine the effect of resistance and reactance on the hunting of synchronous converters and other synchronous apparatus. The synchronous machine for this test was provided with very high damping power in order to obtain extra good conditions. The results in general indicated that a high ohmic drop between the generator and the synchronous load was harmful, depending upon the amount of drop. With 25 per cent ohmic drop, there was almost sure to be hunting, even with an extremely well damped machine. With 20 per cent ohmic drop, the hunting was the rule, rather than the exception; while with 15 per cent drop, hunting might occur, under some conditions, but in fact, it was the exception, rather than the rule. With materially less than 15 per cent ohmic drop in the circuits, apparently no hunting was produced.

Similar tests made with reactance instead of resistance, showed that, up to as high as 60 per cent reactance in the line, there was no material effect, as far as hunting was concerned. In consequence, the conclusion was reached that resistance, rather than reactance, was the harmful element in a large line drop.

The interesting fact about these results is that all

later experience which the writer has encountered agrees pretty closely with these early tests, and in a number of instances he predicted in a given system the conditions of load under which hunting would be first noticed and the results checked closely with his predictions.

After the development of the damper for converters, it was soon discovered that the amount of damping capacity on each machine had not only an appreciable effect in eliminating its own hunting, but it also had a damping effect on the system as a whole, and thus lessened the trouble on other converters. Just as it had been found that one sensitive converter connected to an apparently stable system might set other converters to hunting, so was it found that one especially stable converter with good dampers would tend to lessen the hunting on other converters. In one case, where 60-cycle converters without dampers had been installed, in connection with a waterwheel plant, there was, occasionally, slight hunting, principally under heavy load. The customer requested that an attempt be made to overcome this trouble. As additional converters were being installed, he was told that the trouble would be lessened when the new converters were put into operation. He was very doubtful about this, but upon the installation of the new machines, he reported that the hunting of the earlier machines was overcome. This was accomplished by putting quite ample dampers on the newer machines, thus introducing a steadying element into the system. In another case, in a large interurban railway system, it was found that the converter substations, farthest from the main generating plant, were subject to hunting on heavy load. In this case, a new substation on the same line, but still farther away, was equipped with converters which had very large damping capacity, and this quieted the substation which formerly had shown signs of trouble.

In 1898 and 1899 the 25-cycle converter was coming to the front very rapidly. In the latter year the Manhattan elevated railway in New York decided to electrify, and the first order for synchronous converters comprised 26 units, each of 1500 kw. nominal rating. Sometime later a similar order for the New York Subway consisted of 34 1500-kw. units. Within a comparatively short time, the total number of converters of this capacity for these two companies aggregated nearly 100. This was far above anything ever undertaken in the direct current generator line, and thus it may be seen that, even at this early date, about twenty years ago, the 25-cycle converter had already outgrown its direct-current competitor.

60-Cycle Converters

As was to be expected, the success of the 25-cycle converter would naturally lead to corresponding attempts to build 60-cycle machines. Here, however, much greater difficulties were encountered than in the 25-cycle, due to inherent limitations dependent upon the frequency. The first real 60-cycle converter built by the Westinghouse company was undertaken the latter part of 1896. This was a 250-kw., 14-pole, 514-revolution machine designed for a range of 230 to 340 volts, this range to be taken care of by variations in the a-c. supply voltage by means of an a-c. regulator. This machine was built without dampers, but, if the writer remembers rightly, it was operated from a generating system driven by a water wheel. Even at this time it was recognized that there was a difference in favor of waterwheel operated plants, for it was noted that certain converters which would not operate very successfully on engine-type generators, would operate much better on waterwheel plants. This was credited correctly to the more uniform rotative speeds of the waterwheels.

Shortly after this, a number of 60-cycle converters were put out, built by the Westinghouse and by the General Electric companies, and both had their troubles from hunting. However, other troubles developed, especially on 600-volt, 60-cycle converters. It was soon found that these machines were quite sensitive to flashing and ultimately it developed that this was due to certain inherent limitations in the machines themselves, as constructed in those days. The limiting peripheral speed of the armature cores and commutators was such that apparently good electrical and magnetic proportions were not obtainable. With the maximum allowable peripheral speed of the cores of those times; namely, about 7000 to 7500 feet per minute, the pole pitch of the machines was only about 12 inches and this did not allow space enough for both a good pole width and an ample interpolar space. If the interpolar space was made wide enough to give the desired commutating conditions, then the pole itself became too narrow to give the necessary pole width to prevent unduly high "peak voltages" between commutator bars. Six-hundred-volt direct current machines with less than 12 inches pole pitch had been good practise, but not with the limitations imposed by the 60-cycle frequency. In the direct-current machine, frequency and commutator peripheral speed do not appear as limitations to the same extent as in a synchronous converter, where the pole pitch and the distance between the adjacent neutral points on the commutator are fixed entirely by those two conditions. In the 60-cycle, 600-volt converter, with a commutator peripheral speed of 4500 ft. per minute, the distance between adjacent neutral points is $7\frac{1}{2}$ inches, regardless of the number of poles or revolutions. Within this short distance of $7\frac{1}{2}$ inches, it was then possible to use thirty-six commutator bars, for 600 volts. With this number of bars, the average volts per bar would be $16\frac{2}{3}$, which was believed to be permissible. However, with the relatively narrow pole face, compared with the pole pitch, as used in the early 60-cycle converters, the peak value of the voltage per bar was nearly double the average, and attained a dangerous value in regard to flashing, in machines of relatively large capacity.

However, if on these early converters the poles were made considerably wider, while retaining the same pole pitch, as was attempted from time to time, the dangers of flashing due to high voltage between bars, was lessened, but the neutral or commutating zones then became so sharply defined that it took an expert to operate the machines without dangers of flashing from improper setting of the brushes. It plainly was a case of "between the devil and the deep sea." Obviously, whichever way we moved we encountered either a serious sparking or a flashing condition. Evidently, there was something fundamentally wrong. Adding to the above difficulties the fact that 60-cycle engine-type generators, as a rule, were inferior to 25-cycle units, in constancy of frequency, ability to operate in parallel, etc., it may be seen that the 60-cycle problem was not any too promising for 600-volt work, even with dampers to prevent hunting. However, even when the damper was sufficiently developed on 25-cycle converters to show its capabilities, it was soon found that equally good results were not obtainable in 60-cycle converters, for it was not possible, with any of the designs brought out at the time, to apply anything like as large damping capacity, as was possible with 25 cycles. The 60-cycle poles were much smaller than the 25 cycle, thus allowing less space under the poles. Furthermore, with the higher frequency, the open armature slots produced quite heavy eddy current losses in the dampers themselves. Nevertheless, with all these disadvantages, dampers were applied to many of the early 60-cycle machines with material benefit, especially on units operated from waterwheels.

While the damper was being developed for 60-cycle converters, an interesting discovery was made by one of the engineers installing these machines on a Western transmission system. Here, there was considerable hunting at times, due, apparently to ohmic drop in the line. The generators were waterwheel driven. Hunting of the converters was more pronounced with heavy loads, indicating line drop as one cause of the trouble. In this converter station there was a 100-h.p. induction motor for driving certain apparatus. The installing engineer, noticed that hunting never occurred when this induction motor was connected to the circuit. In consequence, when hunting did occur with the motor off the circuit, he deliberately threw it on the circuit to determine whether it really did have any effect, and it was found that in every instance this stopped the hunting. Following up this clue, in another installation where there was severe hunting of, 60-cycle engine type generators, operated in parallel, and with converters operated from these generators, the writer purposely prepared a special induction motor to operate in parallel with the converters. This was a motor of a normal rating of 50-h.p., but which was operated under such increased voltage conditions that the magnetizing current was about equal to the rated full load current of the motor. In this way a machine of very low reactance was obtained. This motor was also made with relatively small slip. When this machine was connected to the above system in parallel with the converters, it invariably stopped the hunting of the latter, even though there was hunting between the two generators which supplied the converters. For a time, this was looked upon as one possible solution of the hunting problem, but further perfection of the dampers on the converters themselves so far eliminated the trouble, that the induction motor method of damping was abandoned. This is simply given as an illustration of one of the methods which was attempted for overcoming this trouble.

However, taking everything into account, the 60-cycle converter was considered by many operators to be a rather questionable device. Many engineers were of the opinion that the defects were of too fundamental a nature to be overcome. However, the writer believed during all this strenuous period, that the limitations in the converter itself were principally those of experience and practise, rather than true physical limitations, and that advances in the art of construction would allow them all to be overcome in time. He therefore persistently advocated that the 60-cycle development be continued.

A next step, which was of material benefit to the 60-cycle converter, and also to the 25-cycle for that matter was the advent of the turbo generator. This eliminated the element of periodic frequency variations found with the engine type generators. This was of very considerable benefit, eliminating one of the main causes of hunting. However, even with this improvement, the 60-cycle converter was still considered more or less questionable, due to its sensitiveness to sparking and flashing.

While this early 60-cycle development was going on, other quite different developments occurred which have been of great value.

The 3-Wire Converter

In 1897, the writer, while studying some of the conditions occurring in synchronous converters, discovered certain curious characteristics. It was well known that if one lead of a circuit were connected to one of the d-c. brush arms of a converter, while the other lead was connected to one of the collector rings, a pulsating unidirectional e.m.f. could be obtained, varying from zero to a maximum represented by the d-c. e.m.f. of the converter itself. This is illustrated in Curve 1, Fig. 2. The writer was endeavoring to apply this characteristic in some way, and in his study he assumed the case where the one terminal, instead of being connected to the collector ring, or transformer terminal, would be connected to the secondary of the transformer some distance in from the terminal. It developed at once that this would also give a pulsating unidirectional e.m.f., as in the former case, but with lower peak value,

and with its minimum not quite down to zero. This is indicated in Curve 2, Fig. 2. Of course, the next step was to move still further in on the transformer, giving current conditions as in Curve 3. From this, it could be inferred, at once, that if the terminal were moved to the middle of the step-down transformer

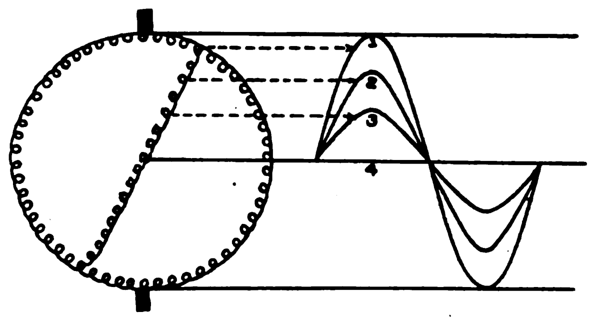


FIG. 2

coil, then the resulting e.m.f. would be constant in value and of half the value of the d-c. e.m.f. of the converter itself. In other words, this tap at the middle of the transformer secondary would give an intermediate voltage between the two d-c. brushes; that is, it constituted a three-wire machine. The writer immediately tested the scheme and found that it did give this result. Incidentally, on the heels of this discovery, a proposition came up where a customer wanted a three-wire system supplied by 60-cycle converters. The writer then proposed the use of a standard type two-phase, 60-cycle converter, but gave no explanation of the method by which it was intended to obtain the mid-voltage. The salesman on the job accepted all statements in blind faith and assured the customer that it could be done, and the customer also bought it on faith. The salesman then came to the factory to find what he had sold. He was soon convinced that he had made no mistake, but he refused to tell the customer how the result was accomplished until the machine was being installed. This method of supplying three-wire systems was used quite extensively in the following years.

THE INVERTED CONVERTER

Another development had to do with the operation of "inverted" converters. After converters had come into general use, a number of occasions developed where it was desired to operate them from d-c. to a-c., and, under certain conditions, more or less instability of speed was noted. This condition had been encountered quite early in the Westinghouse tests, and undoubtedly, similar conditions had occurred to all manufacturers. As early as 1895, a Westinghouse converter on test operating in connection with various other apparatus had suddenly speeded up, and before anyone could do anything, the armature windings had burst. This was blamed on the carelessness of the tester, in accidentally weakening or opening the field circuit, but he insisted that he had done no such thing and he was finally "let off" with a reprimand and told not to do it again. However, some months after this, a converter of fairly large capacity was installed in the company's power plant, tying the a-c. and d-c. power systems together. The first Saturday afternoon, after this machine was installed, the switchboard operator noted that the a-c. load on the plant had fallen to a point where the converter could carry it all and therefore he decided to cut out the a-c. generators and carry all his a-c. load through the converter. It so happened that this load consisted almost entirely of magnetizing current for a large number of induction motors which were running empty. The moment the operator transferred this load to the converter, the latter speeded up so quickly that it burst the armature windings before the operator could reach any disconnecting switches. The writer was at once called in and as soon as he heard the facts of the case, the explanation was simple enough and he stated that, of course, the converter would run away, for the wattless current in the armature would have a demagnetizing effect, just as in an a-c. generator, and therefore the converter had "killed" its own field. He was then asked what remedy could be applied to avoid future trouble. He said, offhand, that as the converter ran away, the remedy should be one depending upon change in speed. He then suggested that the converter be separately excited from a small generator driven in such a way that the exciting generator would speed up directly with the converter, and thus furnish greatly increased excitation with increase in speed. He suggested that this might be accomplished by belting a normally unsaturated exciter to the converter in question, or by exciting from a small motor-generator set, consisting of a d-c. generator driven by an induction motor, the latter to be connected permanently to the a-c. side of the converter. A motor-generator set of this description was soon "rigged up" and afterwards operated in connection with this converter with entire success and the trouble was never repeated in this plant. In later practise, the exciters for such inverted converters were usually direct coupled; that is, placed directly on a shaft extension of the converter itself. This use of a separate exciter was later adopted by other companies and is used today where inverted operation, with highly inductive loads, is one of the requirements. An interesting point in connection with this scheme is that although proposed off-hand some twenty-three years ago, no truly alternative method has ever been brought out.

VOLTAGE REGULATION OF CONVERTERS

After synchronous converters had become more or less accepted practise, it was found necessary to develop some means for varying the voltage of the direct current for railway work and for other kinds of service, such as three-wire systems. The latter was possibly the more pressing need. It was recognized quite early that the most effective method of regulating the d-c.

voltage in synchronous converters was by varying the a-c. voltage supplied. This led first to the application of "step-by-step" a-c. voltage regulators, and later to the use of "induction type" regulators. The General Electric Co. led in this latter practise, as it encountered the need for it most largely in connection with three-wire Edison systems. The first polyphase induction regulators were therefore applied by the General Electric Co. to the Edison three-wire plants. The Westinghouse company also built a large number of synchronous converter units with induction regulators for similar plants. This was quite firmly established practise for several years. However, the induction regulator, especially for a wide range of voltage, was a large complicated, and expensive piece of apparatus and electrical engineers were looking about for some means to overcome these objections.

About 1894, Mr. C. F. Scott, with the Westinghouse company, proposed in connection with compounding railway converters, that the a-c. voltage supplied to the converter be boosted proportionally to the load, by means of a small a-c. generator on the shaft of the converter, the field of which would be excited by the direct current from the converter itself. In this way, a true compounding action, such as in d-c. railway generators, could be obtained. While this particular scheme was never used, it contained the essential elements of a later development which eventually threw the induction regulator in the discard, as far as converters were concerned.

Previous to 1906, the British Westinghouse Co. had built a number of converters with small a-c. generators (or synchronous boosters, as they are now called) connected to the a-c. side, such boosters being separately, instead of series excited. They thus differed from the above scheme only in the method of excitation. In 1906 the Westinghouse company in America built a 500-kw. converter, along the same lines, for the Carnegie Steel Co., of Youngstown, Ohio. However, before this machine was put into service, this type was suggested to the engineers of the New York Edison Company as an alternative to the induction regulator scheme. Its possibilities so appealed to them that they placed an order for a comparatively large machine, in the latter part of 1906. The records indicate that this was the first synchronous booster converter put into service in this country and it thus represents the real beginning of the modern booster type converter in this country.

About 1907, the General Electric Co. brought out the so-called "split-pole" converter, in which the ratio of the a-c. to the d-c. voltages of the converter itself was varied by changing the field flux distribution; and soon the usual fight was "on" between the two companies, regarding their respective methods of voltage regulation. Whatever the merits of the methods, as understood at that time, one definite result was that the polyphase induction regulator soon dropped out of sight, as far as new synchronous converter work was concerned.

As to the relative merits and demerits of the two methods, the split-pole arrangement (or regulating-pole arrangement, as it properly should have been called) required no auxiliary machine, but on the other hand, it was inherently larger than the booster type and it was not well adapted for certain conditions of operations. There were points in favor of each type of machine, but with the coming of the commutating-pole construction, the synchronous booster type presented very material advantages, as the regulating-pole type of converter became unduly complicated with the addition of commutating poles, or their equivalent. In consequence, the booster type eventually won out.

In the synchronous booster type, two general arrangements were put on the market: First, the Westinghouse type with the a-c. regulating generator connected between the collector rings and the armature winding of the converter. In this type, the booster was necessarily of the rotating armature type, with a stationary field, just like the converter itself. In the second type, put out by the General Electric Co., the booster was of the rotating field, instead of the rotating armature type, and was connected between the transformers and the collector rings of the converter. In general, it was placed outside the synchronous converter bearing, on an extension of the armature shaft. There were arguments as to the relative merits of these two constructions. However, the rotating armature type of booster eventually proved to have enough advantages to dominate the situation, so that this type has been adopted almost exclusively. Apparently compactness, general simplicity and neatness of appearance of this arrangement had much to do with its adoption as a general standard.

However, it must not be overlooked that other methods for varying the d-c. e. m. f. of converters had been proposed and used quite extensively. The principal one of these had been used for a great many years in compounding converters for railway service. From the very first, in synchronous converter work, it was recognized that the power factor of the alternating-current input to the converter could be controlled by varying the excitation of the synchronous converter field. It was also known, even before this, that the power factor of the current in a transmission system had a direct influence on the voltage regulation at the end of the transmission line. With these two facts put together, the conclusion was reached that if a converter was given increased excitation, with increase in load, for the purpose of changing the power factor, the effect of the improved power factor would be to give a more uniform or even a rising voltage at the point where the load is taken off. Therefore, with this in view, the writer suggested, very early in the work, that converters should be compounded for the purpose of maintaining more uniform voltage. In-

dependently, Mr. R. D. Mershon went a step further and proposed the use of additional reactance in the transmission line, in order that the change in power factor could produce a still greater range in voltage. According to Dr. Steinmetz, the General Electric Co. at about the same time had been working along the same lines and had actually built heavily compounded converters for a certain railway application, which machines, however, were destroyed by fire before they were put into operation. Thus, it may be seen that this was a live subject and many people were working on it at the same time. Eventually, this arrangement narrowed down to the use of reactance on the a-c. side of the converter for compounding purposes.

An interesting feature in connection with this compounding was the doubt cast upon it in many large installations. On the Manhattan Elevated and the Subway synchronous converter installations, the customers' engineers were exceedingly doubtful regarding the practicability of series coils for improving the voltage regulation on the d-c. system. The Westinghouse company practically insisted upon putting series coils on these machines, claiming that the future growth of the service would necessitate the compound winding. This was then accepted, with the proviso that these machines have such heavy shunt windings that they could be operated as shunt machines, purely. The converters were built and operated in this manner for some five or six years and then, with poorer voltage regulation due to increase in service, the customers' engineers proposed to put the series coils in circuit, but *to shunt them down to half strength*, as they feared to use full strength. After a couple of years of operation in this manner, they removed the shunts and operated with full series and with correspondingly improved results. This same attitude held in various other places, while in some large plants the converters were ordered specially without any series winding whatever.

Further 60-Cycle Developments

Returning again to the 60-cycle development, it was mentioned before that the introduction of the turbo generator represented considerable improvement in the operation of these machines. However, the most serious limitation in the 60-cycle machines was in the small pole pitch and the small distance between neutral points, as explained before. Meanwhile, there had been considerable development in armature and commutator constructions, and finally the writer took it upon himself to urge a quite radical step in the 60-cycle converter development in the way of very materially increasing the peripheral speeds of both the armature core and the commutator. According to his analysis, a 25 per cent increase in the pole pitch would work wonders in the machine, for all this increase, with a given interpolar space for good commutation, would appear as increased pole width. For instance, with an interpolar space six inches wide for good commutation, and the pole itself six inches wide, making a pole pitch of twelve inches, a 25 per cent increase in pole pitch would mean that the pole could be increased to nine inches in width or would be 50 per cent wider than before. This would represent a very big improvement in the magnetic conditions, reducing the maximum voltage per bar very greatly. Also a 25 per cent increase in commutator peripheral speed would allow a corresponding increase in the number of commutator bars per pole, thus further reducing the volts per bar. These radical steps were taken and this development probably represented the greatest single advance in the 60-cycle synchronous converter design. In the General Electric Co. 60-cycle designs, a similar increase in pole pitch was adopted, but apparently this was considered ample improvement, without increasing the number of commutator bars. The writer is not prepared to say that this conclusion was a wrong one. Anyhow, both companies built more successful 60-cycle converters in consequence of the change in pole pitch, and the flashing troubles, except those due to unusual conditions, disappeared to a great extent. However, in spite of this improvement, these synchronous converters still were comparatively large machines with many poles for a given capacity, and while they more nearly approached the 25-cycle machines in characteristics and perfomance, they still were not considered entirely competitive. It took one more very important step to bring the two frequencies more nearly together.

Commutating Poles in Converters

This next step consisted in the introduction of commutating poles. The commutating-pole construction had been developing for a number of years in direct-current generators and motors and in railway motors, but up to the period of 1910 to 1912, the converters had been practically exempt from this development. There was a good reason for this, however. In the d-c. machine, commutation was a more serious limitation than in the converter, for the large, low-speed converters of that time, in general, had extremely good commutating characteristics. The writer and Mr. F. D. Newbury brought this matter out fully in a paper before the Institute in 1911,* explaining why commutating poles were not considered necessary in existing types of low-speed machines. However, in the discussion, the writer brought out clearly that the real field for commutating poles would be found if the synchronous converter speeds were so increased that commutation became a true limitation.

This is what actually happened a short time afterwards, for soon a rush began toward very much higher speeds in converters, so much so that the high-speed designs could not possibly take care of the commuta-

*Interpoles in Synchronous Converters, A. I. E. E. Transactions, Vol. XXIX, 1910, p. 1625.

tion problem without commutating poles. Both 25-cycle and 60-cycle converters shared in this increase in the speeds. The larger 25-cycle machines had their speeds doubled in a number of cases, by halving the number of poles. In the smaller 25-cycle machines, this could not be done because the number of poles was already as small as could be made, practically. Consequently, the smaller 25-cycle converters did not share to any extent, in the decreased size and cost and in the improved performance of the larger machines.

In the 60-cycle development, however, all the machines, from the smallest to the largest, had a relatively large number of poles and thus there could be a material decrease in the number of poles throughout the whole line, with correspondingly increased speeds, improved performance and decreased size and cost. The improvement in performance of the 60-cycle machines was considerably greater than on the 25-cycle, with increase in speed. In the former 25-cycle converter, the iron loss was a relatively small proportion of the total losses, usually being less than the armature copper loss. Increase in speed represented decrease in both iron and copper loss to a certain extent. In the 60-cycle machines, however, the iron loss in the older machines was relatively high, being sometimes from five to ten times as great as the armature copper loss. Doubling the speed, for instance, reduced this iron loss to practically one-half, or a very much greater percentage of the total loss than in the corresponding 25-cycle machine. In consequence of this and other gains, the 60-cycle machine was improved in efficiency to a greater extent than in the case of the 25-cycle, and was brought so close to that of the lower frequency machine that it became seriously competitive, especially when transformer efficiencies were also included. The gain in cost of the 60-cycle machines was also apparently greater than in the 25-cycle machine, and this also brought them closer together. In fact, the gain in cost and performance in the small 60-cycle machines was enough to make them more than competitive with the corresponding 25-cycle machine, so that for these reasons, as well as certain others, they have practically succeeded in driving the small 25-cycle converters out of the market. Thus, due to improvements in generating or supply conditions, certain radical changes in design, and the addition of commutating poles, the 60-cycle converter has changed, from what was considered a questionable machine, to a most serious competitor of the 25-cycle line. Improved types of dampers have also been a part of this development. In the older types of machines, the 25-cycle units with larger available space on the fields, could have very effective dampers, whereas the 60-cycle was somewhat handicapped in this respect. With the development of complete cage types of dampers, very much like those in the secondaries of cage-type induction motors, both 25-cycle and 60-cycle damping conditions were improved, but the 60-cycle were improved much more than the 25 cycle. This was therefore another step in advance.

Starting of Synchronous Converters

There is another part of the synchronous converter story, which as yet, has hardly been touched upon. This refers to the methods of starting and synchronizing such machines. One method of starting, namely, that used on the Chicago World's Fair exhibition machines, has already been referred to. This consisted in the application of relatively low voltage to the collector rings of a converter, and bringing it up to synchronous speed, after which it was transferred to full supply voltage. This method was practically the same as in present day practise, except that the starting device was somewhat more complex in having several steps, whereas at the present time, rarely more than two steps are used, namely, a starting position and full running position. This early method was not considered practicable, due to the fact that the "pull" on the supply system was thought to be excessive. Voltage regulation for generator systems in those days was entirely by hand and the throwing on of large inductive loads, such as converters at standstill, represented a very difficult condition, especially with the small generating plants in use in those days. At the present time, with the huge plants in use, a converter even though of the largest commercial size, may represent only a relatively small percentage of the power plant capacity.

To overcome the difficulties from a-c. direct starting several methods were devised and used quite extensively. The Westinghouse company in 1895 began using induction motors for starting synchronous converters. The first time that this method was put into service was on a 500-kw. converter in the power station of the Niagara Falls Power Co. This machine, as already mentioned, was one of the World's Fair 500-h. p. machines reconstructed into a 600-volt, 500-kw. machine. A six-pole induction motor was direct connected to the shaft of the converter for bringing it up to speed. It was thought at that time that the problem of starting from rest and speeding up was the serious one, and that as synchronous speed was approached, the current "pull" would not be very serious. However, actual operation on this Niagara converter indicated that the starting motor preferably should be able to pull the converter up to true synchronism. In consequence, on future designs the Westinghouse company installed starting motors which could accomplish this result. This was done by making the starting motor with two less poles than the converter itself, so that the synchronous speed of the starting motor was higher than that of the converter. Various methods were adopted for bringing the converter to exact synchronous speed and holding it there for an interval long enough to allow it to be thrown on the line without disturbance. In some cases, the no-load

losses in the converter, when excited to normal voltage were just sufficient to give load enough to obtain the required slip on the induction motor to hold the converter at approximately its synchronous speed. However, it was an unusual case when this came exactly right. The starting motor had to meet two conditions, namely, it had to have enough torque at standstill to overcome the friction-of-rest of the converter, which sometimes was quite high. As a second point in the speed-torque curve, it had to develop just torque enough at the synchronous speed of the converter to hold a reasonably stable or constant speed at this point. Not infrequently, it was impossible to get a speed-torque curve of the induction motor, which would meet these two conditions, without the aid of auxiliary appliances. For instance, with a six-pole converter and a four-pole starting motor, the motor had to run at two-thirds speed, that is, 33⅓ per cent slip, for synchronizing the converter. Even with a straight line speed-torque curve, this meant that the standstill or starting torque could be only three times the synchronizing torque, and in many cases, this was not sufficient to overcome the friction at start. By supplying higher voltage to the starting motor, a higher starting torque could be obtained, but the torque at two-thirds speed would be increased correspondingly, and consequently, the converter would reach stable speed at some point considerably above that required for synchronizing. One remedy for this in some cases was to greatly overexcite the converter, increasing its no-load losses and thus increasing the slip of the starting motor. This, however, meant throwing into synchronism with the line at considerable over-voltage. A second way of accomplishing the desired result was to throw a small resistance load across the d-c. end of the converter, thus pulling down its speed the required amount. Another way was to connect a transformer, with a cast iron core, across the a-c. side of the converter. All these methods had to do with starting motors with "cage" type secondary windings. In some few cases, starting motors with wound rotors and regulating resistances were used, but this scheme in general, was so much more complicated than others, that it was not used. The synchronizing difficulty, just described, generally occurred only with converters having six poles. With eight-pole converters and six-pole starting motors, the conditions were much more satisfactory, and in general, the higher the number of poles the easier it was to get good synchronizing conditions. However, this method of starting did not apply at all to four-pole converters, for this meant two-pole starting motors and the conditions for synchronizing would have been very difficult. In the later years of the starting motor method, commutator type single-phase series motors were used in some cases for starting, with means for readily adjusting their speed. These could be used with four-pole converters, and therefore were of especial advantage in smaller 25-cycle converters.

The disadvantage of the motor method of starting, in general, was that the converters had to be synchronized with the a-c. system, before throwing in. One advantage of this method was that the polarity of the converters always came right. However, the objections to synchronizing were considered as quite serious and eventually the method, in general, was abandoned, except in special cases.

A second method of starting, which was used in a variety of ways, consisted in bringing the converter up to speed by means of direct current. This method was used more extensively by the General Electric company than by the Westinghouse company. One method was to bring the converter up as a direct-current motor connected to the d-c. system where power was available from other sources. However, in railway work, the d-c. voltage supply often was so variable that it was most difficult to hold the converters anywhere near constant speed after bringing it up. In consequence, synchronizing and throwing into circuit was sometimes a tedious matter. To overcome this difficulty, in some cases the converter was brought very slightly above synchronism by the direct current, disconnected from the d-c. system, and then switched over to the a-c. system as it dropped through synchronism. A third method, which was also used quite extensively, consisted in the use of special sources of d-c. supply, such as motor-generators or storage batteries in the synchronous converter station. The source of supply being of practically constant voltage, there was no great difficulty in holding reasonably constant speed at synchronism, and throwing it on the a-c. system was comparatively easy. This scheme required synchronizing devices just like the starting motor scheme, and moreover, the synchronous converters came up with the right polarity. Where there was a large number of converters in one station, the cost of the motor-generator set, or other means for getting a constant voltage supply, was oftentimes no greater than that of starting motors on each converter.

In starting synchronous converters on direct current, there was one condition which was sometimes encountered, which was a source of more or less trouble. In some instances the step-down transformers, which supplied a converter, were connected permanently to the collector rings of the converter, without switches, all switching being done on the high-tension side of the transformers. In such cases, the low-tension, or secondary windings of the transformers were liable to form more or less complete short circuits across the d-c. brushes of the converter, depending upon how the collector rings were connected to the winding. In two-phase machines, with taps at 180 deg. points on the winding, it is obvious that with these taps in line with the brushes, the direct current supplied for starting could go, to a great extent, through the transformer, instead of the converter windings. In such cases, the

converter was liable not to start. With six-phase converters with diametral connections, the same conditions held. In consequence, with such connections, it was sometimes necessary to help the converter off by mechanical means. Of course, when once in motion, the current into the transformer would be immediately decreased. In six-phase machines with d-c. starting, double-delta connection to the transformers was generally used to prevent severe short-circuiting of this nature. In three-phase machines, dead short circuits by the transformers were not possible, for there were no taps across a diameter, and always part of the armature winding had to be in circuit. Double-delta connection with six phase is, of course, the equivalent of three phase, with respect to short-circuiting. However, even with three-phase converters, the short-circuited affect of the transformers with this arrangement was very considerable. For instance in the 1500-kw. converters for the Manhattan Elevated, motor-generators of 50-kw. capacity were provided for starting the 1500-kw. converters. On shop test, these starting sets were entirely ample for starting the converters, but here the lowering transformers were not connected to the converters. When installed in their substations, however, it was found that these 50-kw. units were very heavily overloaded at times in starting the converters, due to the short-circuiting action of the transformers. Tests were made to determine what influence the position of the collector taps had on the starting torque and current, and it was found that as far as the synchronous converter was concerned, its torque varied over a wide range, depending upon the position of the taps, and in all cases, it was considerably lower than when no transformers were connected. In consequence, to obtain the necessary starting torque, a very greatly increased starting current was needed, thus overloading the starting sets. This difficulty was overcome on the corresponding New York Subway converters by installing starting sets of double the capacity.

However, many years ago, the present method of direct starting by alternating current supplied to the synchronous converter collector rings was used, first on a small scale and afterwards on large machines, because it represented, wherever it was practicable, a cheaper and somewhat more convenient method than any of the others. Although this scheme was developed first by the writer and shown in the Westinghouse exhibit at the World's Fair, as already described, the General Electric Co. was earlier in the field with it on a commercial scale. This method of starting, at first, was considered as more or less of a hardship, as far as the supply system was concerned, but with the early development of an operative voltage regulator for the supply generators, the General Electric Co. was able to make headway with this method.

As the power systems grew in capacity and in size of units, they presented easier and easier conditions, as far as starting converters was concerned, and therefore, this method came into greater and greater use until it practically superseded all others. This method has the advantage that synchronizing apparatus is not needed, and, while it can come up with the wrong d-c. polarity, yet by means of "slipping a pole" this can be corrected very easily. In consequence, the method is, in general, quite satisfactory.

In some cases, in recent years, a combination of the motor starting method and this direct a-c. method has been used. In this special method, the supply current is fed through the primary winding of a starting motor and then to the synchronous converter armature. The starting motor is thus in series with the synchronous converter, and at start and during acceleration a relatively small current flows in the synchronous converter armature, but this current is large enough to produce a quite heavy torque in the starting motor. The small current in the armature of the converter is insufficient to reverse the polarity of the synchronous converter field, so that as the machine comes up to speed, it excites itself with its normal polarity, and when synchronism is reached all that is necessary to do is to short-circuit the induction motor element.

COMMUTATION

The problem of commutation was never very serious in the synchronous converter except in some of the later synchronous booster types where special conditions are found.

One reason why the commutation on the synchronous converter has been a simpler problem than on the d-c. generator is that the magnetomotive force of the armature is relatively small, being the resultant of the alternating and direct currents in the armature, whose magnetomotive forces are in opposition. In consequence, at 100 per cent power factor conditions, the resultant m. m. f. averages only about 15 per cent of that which the same winding would give as a d-c. generator. In consequence, the magnetic field, due to the armature, in which the commutating coils are short-circuited, is smaller than in a d-c. machine, and converters without commutating poles can commutate from 30 per cent to 50 per cent more current than the corresponding d-c. machines. Of course, in practise, converters were not built with this margin in commutation, for their ratings were increased, with a given armature winding, thus taking up a good part of the margin.

However, when it comes to flashing, converters have often proved to be more sensitive than d-c. machines. There have been several reasons for this. In the first place, being tied to an a-c. system, the converter, on a d-c. short circuit, not only could act as a d-c. machine, but could take current from the a-c. supply system, thus giving a very high peak current. In the second place, on a sudden application of heavy load, or on a short circuit,

part of the current, at least, is due to the machine acting as a d-c. generator and, in consequence, the armature m. m. f. is increased enormously over that as a converter. Moreover, under this condition, tests have shown that the converter may tend to hunt badly for a moment. This hunting simply means that the m. m. f. of the armature is rising to a relatively high value, first in one direction and then in the opposite direction, with accompanying field distortion, etc. This explains a rather curious condition, which was noted very many years ago; namely, that converters frequently would flash worse after the d-c. breaker was opened on a heavy load or short circuit, than they did in the moment of application of the load. The sudden load would produce the conditions for momentary hunting, but very often this hunting would not really begin until the breaker came out. In consequence, any flashing due to the hunting action would thus occur after the d-c. breaker was out and the apparent cause of the flashing had been removed. This action was quite clear from some shop tests made to determine the effect of opening the d-c. breaker when a converter was carrying a very heavy overload. The conditions in the tests were such that hunting could be readily determined. It was found that the hunting began the moment a very heavy load was opened by the breaker, and on a well damped converter it lasted for three or four "beats" approximately. In some cases, the hunting action was so violent that there was great tendency to flash at the brushes during this period. Obviously, under such conditions, anything that would lessen the hunting tendency would reduce the tendency to flash. Proof of this was furnished in a curious way in the case of commutating-pole converters, as will be explained later.

When it came to commutating-pole converters, the problem of commutation was even easier than on d-c. commutating-pole machines, except in those cases where the speeds were very greatly increased, accompanying the addition of commutating poles. As was explained before, in the application of commutating poles for synchronous converters, the speeds were doubled, in many cases, in order to improve the performance and lessen the cost. This doubling of the speed made the inherent commutating conditions much more difficult than before and a condition was reached where commutating poles were a real necessity, in order to obtain good commutation, as the commutating constants were about twice as high as in the former non-commutating machine.

A curious situation arose in connection with the early application of commutating poles to synchronous converters. It was well known that in direct-current commutating-pole machines, it is bad practise to surround the commutating pole with any closed low resistance electric circuit, as this acts as a damping circuit to make the commutating-pole flux more or less sluggish, so that it cannot follow quick changes in the load. Naturally it was assumed that in the synchronous converter similar conditions should hold. In consequence, it was assumed that the copper dampers on the main poles of the synchronous converters should not enclose the commutating poles. In other words, a complete cage damper should not be used. The writer recommended this practise* and apparently no one took exception to it. However, later actual operating conditions indicated just the contrary. In one case where a number of large synchronous converters were to carry 300 per cent short-time loads, there was bad flashing when the breakers would come out. The service engineer then put a short-circuited winding on the commutating poles, as an experiment, and found that the flashing was reduced to a certain extent. Tests were then made with full "cage" dampers on the poles of certain converters, these dampers necessarily completely enclosing the commutating poles. These machines flashed to a less extent than any of the others, thus showing that a closed circuit around the commutating pole was more of an advantage than otherwise. The explanation of this was then apparent from tests made to determine hunting conditions when an overload was thrown off, as already described. According to the calculations, the complete cage damper had about twice the damping effect of other types of dampers, and in consequence, the hunting, with sudden removal of load, was very much diminished. Therefore, the reduction in the hunting tendency apparently very much more than counterbalanced any bad effect of the low resistance circuits around the commutating poles.

This effect of the complete cage damper in preventing flashing is apparently much more pronounced in commutating-pole machines than in the old non-commutating-pole type for the following reasons:

In the commutating-pole converter, the magnetomotive force on the commutating-pole winding is comparatively small, as it must overcome only the small resultant armature reaction, averaging about 15 per cent of the d-c. plus about 20 per cent commutating field. This winding thus is made about 35 per cent as strong as the m.m.f. of the armature itself, considered as a d-c. machine. The corresponding commutating-pole m.m.f. of a d-c. machine could be about 125 per cent. It may thus be noted that the commutating pole m.m.f. of the average converter is only about one-third that of a corresponding d-c. generator. Here is a source of possible trouble; for, if for any reason, such as hunting, the resultant armature m.m.f. rises to a value comparable to that of a d-c. machine, it very greatly overpowers the commutating pole winding, and in consequence, magnetizes in the opposite direction through a good magnetic circuit. The commutating-pole flux thus may not only be reversed, but may rise in the wrong direction to a value which will give most vicious sparking, thus tending to produce flash-

*Discussion of "Interpoles in Synchronous Converters" loc. cit.

ing. In consequence, when a commutating-pole converter hunts badly, with the resultant m.m.f. rising to high peak values, there is a very great tendency in such machines to flash during such hunting. In consequence, anything which will reduce hunting will lessen this flashing condition. Therefore, the complete cage damper, as described before, with its ability to reduce very much the hunting tendency, has been quite effective in reducing flashing tendencies.

When it came to building "booster" type converters capable of giving a fairly wide range in voltage, a new difficulty was encountered, particularly in commutating-pole machines. An analysis of the armature conditions showed that under different loads with different "boosts" and "bucks" the resultant armature m.m.f. is not proportional to the current output of the machine. In consequence, it is not practicable to excite the commutating poles in series with the leads from the commutator, as in the ordinary converter. Neither will a shunt winding or direct combination of series and shunt meet the required conditions. In consequence, it has been necessary to develop very special regulating methods for exciting the commutating-pole windings for the synchronous booster type of machine. This has been a quite difficult problem, but eventually practical schemes were developed which enabled the commutating poles to be excited to a suitable value at all times. This has been one of the most difficult problems encountered in recent synchronous converter work, not due to any misunderstanding of the problem itself, but because no simple, easy method for accomplishing this result could be developed for quite a long time.

Commutators, Brush-holders and Brushes

From the standpoint of the commutator itself, the greatest development in recent years has been toward rigid constructions with higher peripheral speeds. With decrease in the number of poles and increase in the revolution per minute for a given output, the number of brush arms has decreased and the diameters of the commutators have decreased materially and the lengths have increased. A smaller diameter, with a higher peripheral speed and a greater length, means a materially more difficult mechanical construction, and this has been one of the serious problems in synchronous converter construction. The currents per brush arm have increased from 400 or 500 amperes up to 1500. This development has been accompanied by a certain amount of service trouble, as short-time shop tests cannot possibly bring out all the difficulties nor show how to overcome them permanently. However, enormous progress has been made in this matter and, presumably, the commutator situation is as good at present as in the past.

As to d-c. brush-holders, these have also gone through considerable development. In the early days, the problem was simpler than at present, for various reasons. In the first place, with lower currents per brush arm, there were fewer brushes per arm and less difficulty in obtaining average distribution of current among the brushes. With increase in current per arm, this problem has become relatively more difficult. In the second place, brushes of somewhat lower resistance have come into use and these have made the problem of distribution of current also more difficult. In the third place, with the coming of commutating poles there has been the necessity, in large converters, for development of brush lifting devices in connection with bringing the converters up to speed by the direct application of alternating current. In the old non-commutating-pole converters, the coils short-circuited by brushes were located in a relatively large interpolar space, with no iron directly over them. In starting and acceleration, the synchronous converter armature is simply the primary element of an induction motor, the field structure being the secondary. A rotating or traveling flux is set up, but in the vicinity of the coils short-circuited by the commutator brushes, this flux is of quite low value in non-commutating-pole machines due to there being no iron over the coils. In consequence, the short-circuiting effect of the brushes was not seriously harmful. In the commutating-pole machine, however, especially in large sizes, the commutating pole itself, during starting, furnishes a good magnetic path directly over the short-circuited coils, and in consequence, a quite heavy flux is established at these points. This develops quite large e.m.f's. in the short-circuited coils, with consequent heavy sparking during acceleration. For this reason, it has been found desirable to install brush-lifting devices to take care of the starting. When it is considered what a large, complex structure the brush-holder system forms in a large converter, it may be appreciated that this brush-lifting device adds very considerable complication and this has been one of the difficult problems in modern design.

Collector Rings and Brushes

Taking up next the question of collector rings, it would appear, offhand, as if the collector rings represent a comparatively easy problem. But in fact, it has become one of the truly difficult problems in the converter design, especially in recent years. Just to look at the collector and to note its functions, one would say that it is simply a matter of building several rings and putting on suitable brushes; but the matter goes far beyond this. The quantity of current to be handled is one of the sources of trouble, especially in the modern high-speed machines. When one considers that the total current to be handled by all the collector rings is practically three times the current delivered by the direct-current end (or neglecting efficiency, $2 \times \sqrt{2} \times$ d-c.) one can appreciate that the problem is largely one of quantity of current. However, the commutator handles the direct current twice, so that the total current handled by all the collector rings is approxi-

mately one and one-half times the total handled by the commutator. Yet, one usually looks upon the collector as being, naturally, a small inconspicuous part of the converter, whereas the commutator is one of the large important parts. It is this heavy current to be handled which has been at the bottom of nearly all collector ring difficulties in converters.

Very early in the development, converters were made either two-phase or three-phase; that is, with four collector rings or three. In this case, however, as all the rings are connected to one common winding, two phase is really four phase, and therefore, we may say that the early converters were either three-phase or four-phase. In the earliest calculations of the losses in synchronous converters, as already described, the three-phase machine showed 57 per cent of the copper losses of a d-c. armature winding, whereas the two-phase (or four-phase) showed 38 per cent. Obviously, the losses decreased with increase in the number of phases, or collector rings. Mr. R. D. Mershon worked this out at a very early date, and his calculations showed that with six-phase the losses were about 26 per cent, and that with enormous further increase in the number of collector rings, the losses would be decreased to 12 per cent. The general conclusion was that six rings represented a very considerable gain over four rings, but that it would not be worth while to go further than six. Mr. Mershon, the writer believes, was the first one to propose the use of six collector rings for synchronous converter work. However, this suggestion was not adopted until some years later, as there was apparently no particular advantage, in the early machines, in going beyond three or four rings. However, when quite large 250-volt machines came into use, as for Edison three-wire systems, the General Electric Co. adopted the six-ring arrangement, with transformers connected in double delta. It was not until a considerable time later that the simpler arrangement of "diametral" connections, now used so generally, was adopted. This latter arrangement was so simple that it gave an impetus toward the six-ring arrangement, which has brought it into quite general use, so that at the present time practically all converters are made six-phase. In the earlier work, the General Electric Co. adopted three-phase quite generally, whereas the Westinghouse used four-phase. Here was one case where the two-phase, so-called, had some advantage over the three-phase, but in going to six-phase (this is in reality a true three-phase, as far as the supply system is concerned), the advantage was in favor of the three-phase system.

In considering the collector rings themselves, the earliest types were made in the old-fashioned way, entirely enclosed on the sides, by the intervening insulating barriers, and therefore, with no ventilation except at the wearing surface of the rings. Copper leaf brushes were used, with relatively small contact drop, and therefore for moderate current capacities the losses were not high. However, with more difficult conditions, it was soon found that there was undue heating of the rings and the "open" type of collector was developed, in which the rings themselves were carried on open arms or spokes, so that the air could circulate freely. This enormously increased the carrying capacity of the rings and was a big step in advance. As a rule, several leaf brushes were used on each ring, as it was found that the ordinary brush could carry only about 200 to 250 amperes and very often the current per ring was several times this. A curious thing developed early in this work in regard to collector ring "wear." It was discovered that in some cases the rings would get "out of round" in a peculiar way. In a six-pole machine, there would be three high spots and three low spots on the ring, equi-distantly spaced; in an eight pole machine, four highs and four lows, etc. As soon as this was noticed as a serious defect, the cause was also recognized, for similar conditions had occurred in rare cases in rotating armature alternators, in the early days. The difficulty was not due to actual mechanical wear of the collector rings, but to burning under the brushes. It was recognized in a general way, long years ago, that a current passing from a brush to a commutator or ring in motion would tend to burn or "eat" away the brush surface, but not burn the ring to any extent; while in passing from the ring, or commutator, to the brush, the former would burn but not the latter. In the commutator, both actions take place due to both polarities being on the same commutator, and therefore, the effect is not usually noticeable. However, in the converter collector the current passes alternately in each direction in the rings, but assuming a single brush on the ring the current would be from the ring to the brush in one part of the ring, representing one pole arc, and would be in the opposite direction in the part representing the next pole arc. Consequently, within a given segment or part, the current is always in a given direction with respect to the brush and the ring. In consequence, in one segment the ring would tend to burn away, while in the next segment it would not. Consequently, if there were any burning of the rings, they would tend to get out of round, with as many low spots as there are pairs of poles. In some of the early converters, in laying out the brush spacing, accidentally the brushes were so spaced, with respect to the rings and the poles, that this burning action was accentuated, while in other machines, the spacing of the brushes was such as to give pretty uniform burning tendency over all the ring. In consequence, in some machines the rings would run out of true, while in others they would not. As soon as this became of sufficient importance to attract attention the difficulty was overcome by remodeling the brush supports and respacing the brushes. It was also noted that this action was particularly bad with very high current densities, and in such cases, the brush capacity was increased materially to lessen this effect.

The copper leaf brushes, being very flexible, could follow quite easily any slight variations out of true. Moreover, with low contact drop and the good ventilation of the open construction, the rings ran at relatively low temperature. Consequently, undue expansion did not come in as a factor, as has proved to be the case in some of the latter work. However one serious objection to the copper brush was that its wear resulted in a deposit of fine copper dust over everything and considerable attention was required to keep the parts clean and to keep the brushes just right. However. this method of operation lasted until comparatively recent times, when the "metal graphite" brush came in.

Many years ago, certain brush manufacturers in Europe produced graphite brushes with fine metal particles in them, which appeared to have very good carrying qualities, with low contact resistance; this latter being about one-fifth that of an ordinary carbon brush. With such brushes available, the manufacturers of synchronous converters undertook to use them on collector rings to overcome the objectionable features of the copper leaf brushes. These brushes were tried on quite a number of machines of different types, with both favorable and unfavorable results. It was found that the current densities, claimed practicable for these brushes, were, in general, much too high for American practise, and therefore, much larger brush capacities had to be adopted. Special brush holders had to be devised to meet the brush characteristics and a number of new difficulties were encountered which had not appeared with copper brushes. One of these was the effects of irregularities in the collector rings themselves. With copper brushes, as stated before, the rings could runout of true slightly, without having any appreciable effect. It was soon found, however, that with the metal graphite brushes, the rings could not be out of true, to anything like the same degree, as the brushes could not "follow" the surface properly and maintain sufficiently intimate contact. In other words, there was a "heel-and-toe" contact when the rings were out of round, with momentary local high current densities between the brush and the rings, with corresponding tendency to burn.

Also, with the higher contact brush resistance, there are considerably greater losses in the rings and brushes than with copper brushes, and in consequence, greater heating of the rings results, accompanied by greater expansion. As the rings, especially in the larger machines, must be of some "spider" type construction for ventilation purposes, it has been a serious problem to design rings which would not warp out of round with increase in temperature. A very considerable amount of difficult engineering has been carried on, to overcome the various troubles and to maintain, at the same time, good ventilation. In the recent years of synchronous converter work, there has been, possibly, no more difficult problem than this one of collector rings with graphitic brushes.

The foregoing pretty nearly completes the technical story. Something further might be said regarding special constructions of machines, such as very small converters, high voltage machines, etc.

In the very small synchronous converter, there has been possibly more trouble, in proportion, than in any of the larger sizes. This is partly due to the fact that in the small machine there is insufficient room for good size dampers, without making the machine unduly large. Such machines also appeared to be very sensitive to prime mover and transmission drop conditions, possibly on account of the small damping capacity. Some years ago the writer made a small converter of about 1½ kw. of the induction type, as already described. The principal purpose in this was to make a machine which absolutely would not hunt under very bad supply conditions. This little machine was later tried out on a generator plant where the generators themselves would not successfully parallel with each other, and yet it operated without any hunting whatever. Of course, being of the induction type, its power factor was comparable with an induction motor of about the same capacity. This was a most interesting little machine, and the writer has always believed that something further could have been accomplished with this principle.

In high voltage railway work, which has developed in recent years, there has been a call for synchronous converters of 1200 and 1500 volts and many outfits of this nature have been built. For 60 cycles, it has always been the practise to couple two machines in series, as it appears to be physically impossible to make a good 1500 volt, or even 1200 volt, 60-cycle converter with one commutator. Two-commutator machines have been proposed, but apparently this leads to considerable complication, so that the two-unit arrangement is the only one which has been commercial.

In 25-cycle converters, it has been practicable to build single machines up to 1500 volts with first-class operating characteristics. However, apparently there has been no attempt, up to the present, to operate two of these in series, commercially, to give 3000 volts.

Two-phase, three-phase and six-phase converters have been considered. Obviously, at some time in the development, single-phase converters necessarily came up for consideration. Very early in the development, the analysis of the losses showed that, when operating on single-phase, a synchronous converter would have considerably greater armature copper losses than on direct current alone. Consequently, this method of transformation was not considered as economical. However, from time to time, cases came up where single-phase operation was necessary, under emergency conditions, and in one case, a moderate size converter was operated for several weeks on single-phase supply with apparently no harmful effects. However, it was noted, in a large synchronous converter, transforming

from d-c. to single-phase, that there was considerable vibration of the dampers, these eventually becoming so loose that their supports had to be changed to more substantial ones. It was recognized that this was due largely to the backward rotating component of the a-c., m.m.f. the magnetizing effects of which were very largely neutralized by the dampers in the poles. This introduced a double-frequency current in the dampers themselves, which set up vibration. Apparently, however, when these dampers were properly constructed, a well proportioned single-phase converter would operate just about as well as polyphase, except for higher losses and other inherent conditions.

In conclusion of this paper, something might be said in regard to recent growth of the converter business. As already explained, at the time of the Manhattan Elevated and the New York Subway work, the 1500-kw., 25-cycle units had the "call" and it was felt, at that time, that while larger units might be used occasionally, the field was not large enough to call for much larger capacities. However, a few years later, 2000-kw. units were bought on a comparatively small scale, and then a few 3000-kw. were built. It then developed in quite a short time that a still larger unit was advisable for the heavier service and the 4000-kw., 25-cycle machine came in with a rush, which size has proved very desirable for heavy work. On 25-cycles, many of these units have been built by both the larger manufacturing companies. However, little has been said about still larger units, so that apparently this 4000-kw. size seems to meet all the needs at present.

In 60-cycle units, some seven or eight years ago, there was a sudden increase to 1500-kw. as a standard unit, although occasionally before this, machines as large as 2000 kw. of the slow-speed type had been installed. With the coming of the higher speeds, commutating poles, etc., and improved constructions, the 1500-kw., 60-cycle converter has proved to be a good one for railway work, while units of 2500 kw., and even larger, have been used very extensively for lighting purposes, electrochemical work, etc. In consequence, the 60-cycle and the 25-cycle converters are coming closer together in sizes, as well as in performances.

As to the future, no one can say where the upper limit will be, in the capacities of synchronous converters. It is practicable to build any capacity that the electrical public will pay for, as it is simply a question of increasing the number of poles, and decreasing the speeds, until the desired capacity is obtained. It may be said that it is a question of cost entirely, and not of design. However, in 60-cycle machine, there is still opportunity for relatively higher speeds, as the number of poles for a given output is still much less than in corresponding 25-cycle machines. In the latter, apparently the upper limit in speed has either been reached or we are very close to it. In 60 cycles, we cannot say that we have yet reached the limit of speed.

This rounds out the story of the synchronous converter up to the present. The early part of the story may appear more interesting than the description of the later developments, possibly because the early stages in any development possess more novelty, and also it may be that we obtain a better perspective of the more distant period. The later developments were, in many instances, just as difficult as the earlier ones, but they were part of an old story.

The present high stage of development of the synchronous converter is necessarily the result of the cooperation, as well as the competition, of many able minds. The writer wishes it to be understood that his engineering associates, as well as the engineers of other manufacturing companies, should share in the credit for this great development. From the personal references in the body of the paper, it might be inferred that he did practically everything himself; on the contrary, except in the early stages, in many instances he acted largely in an advisory capacity in the various developments, thus keeping in close touch with the problems at hand.

TEST OF A NEW ELECTRIC LOCOMOTIVE

ONE of the five new electric locomotives built by the General Electric Co. for a new electrified branch of the Chicago, Milwaukee & St. Paul Railroad, was recently tested at Erie, Pa., the tests being witnessed by a large number of engineers and railroad men, including officials of the Chicago, Milwaukee & St. Paul, the General Electric Co., the Canadian National Railways, the Canadian Pacific, the Hydro-Electric Power Commission of Ontario, and others. The new locomotive which is of the gearless type is one of the most powerful locomotives in the world. It has 14 axles each of which carries a motor. It is equipped for operation at 3000 volts d-c. and has a capacity of 3240 h.p. It is 78 ft. long, 17 ft. high and weighs 265 tons, of which weight 229 tons is carried on the drivers.

These locomotives have been designed for handling in normal service a 12-car train weighing 960 tons, against a two per cent grade at 25 miles per hour. Tests have showed that the gearless type of locomotive has 10 per cent higher efficiency at 50 miles per hour than the geared type. These locomotives are provided with regenerative brakes by means of which current is fed back into the line by the locomotive when it is coasting on down grades.

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with which is incorporated the PROCEEDINGS of the A. I. E. E.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

THE NEW JOURNAL

The JOURNAL, formerly called the PROCEEDINGS, appears this month in a new form. The changes in name, size, and scope constitute one result of the deliberations of the Institute's Committee on Development, which formulated recommendations embodying improvements in the activities of the Institute, based upon the response of the membership to the Committee's request for suggestions.

The numerous replies received from members, and the reports of meetings of the Sections of the Institute held throughout the country for the purpose of considering these matters, clearly indicated a very general demand that the Institute continue to publish a high grade electrical engineering periodical, including, however, not only material of the nature heretofore published and consisting principally of engineering and theoretical papers and discussions presented at the various meetings of the Institute, but also much additional matter, relating to progress in the art of electrical engineering, selected with the object of publishing in each issue something that will appeal to each reader.

The broadened scope of the publication is a logical step in the evolution of the Institute based on the constructive work of the past, the present purpose being to supply information that will enable the individual engineer to keep more fully informed of recent developments in the *theory* and *practise* of all branches of electrical engineering. Original papers on theoretical or experimental investigations, important inventions, discoveries and developments in the fields of electrical engineering and the related sciences, will continue to constitute the major portion of the JOURNAL. The high standard that has always been maintained in the contents of the Institute's publications will be continued.

The dimensions of the page have been increased to 9 by 12 in., the generally adopted standard size for technical periodicals. It is more economical to publish the same amount of material on pages of the larger size than on the smaller size heretofore used. The larger page also permits a more attractive typographical display, a better arrangement of tabulated matter, and the publication of larger illustrations. Many other professional societies have adopted substantially the same size, including the Institution of Electrical Engineers of Great Britain, the Engineering Institute of Canada, the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the American Institute of Mining and Metallurgical Engineers.

The improvements in the JOURNAL and in other activities of the Institute, as recommended by the Committee on Development, reflect the trend of the times. The predominating idea of today is social progress. The engineer, because of his training and experience, is particularly well qualified to analyze facts and draw conclusions. There is a general feeling, however, that the engineering profession has refrained from contributing the complete service of which it is capable in the consideration of the great social and economic problems which underlie human progress, and which require for their solution the application of engineering principles and methods.

The leaders in the engineering profession are the men who have been most active in their respective professional societies. Their ability for effective collective effort has been developed to a large extent by their activities in the Institute and in similar organizations. The JOURNAL is one of the instruments provided by the Institute for the exchange of ideas and it affords an opportunity for the individual engineer to contribute for publication something of interest and value from his experience in exchange for the ideas which he receives from other contributors.

The Publication Committee will therefore be glad to consider for publication contributions similar in scope to those published in this issue, in which a beginning has been made in the direction indicated. Additional improvements are under consideration, the development of which must necessarily be gradual and within the available income of the Institute applicable to publicatons. It is expected that the future issues of the JOURNAL will constitute even more fully than the monthly PROCEEDINGS and the annual TRANSACTIONS have in the past, an authoritative history of developments in the electrical engineering art and the related sciences, upon which evolution in the electrical industry is based.

A. I. E. E. MEETING AT CHICAGO

The 357th meeting of the American Institute of Electrical Engineers will be held in Chicago, Ill., January 9, 1920, under the auspices of the Chicago Section and the Lighting and Illumination Committee. The Western Society of Engineers and the Chicago Section of the Illuminating Engineering Society have been invited to participate in this meeting.

The headquarters of the Institute during the meeting will be at the Western Society of Engineers' Rooms, 17th floor Monadnock Block, where the registration and afternoon technical session will be held. An informal dinner and the evening technical session will be held at the City Club, 315 Plymouth Court.

The subject of the technical sessions will be *Electrical Distribution for Street Lighting.*

The complete program is as follows:

PROGRAM

Friday, January 9, 10 a. m. At Headquarters

Registration.

Board and committee meetings.

Friday, January 9, 2 p. m. At Headquarters

The Series System of Street Lighting, by W. P. Hurley, Sales Engineer, Westinghouse Electric & Mfg. Co., New York.

Multiple Systems of Distribution for Street Lighting, by Ward Harrison, Engineering Department, National Lamp Works, Cleveland, O.

Friday, January 9, 6 p. m. Sharp

At City Club, 315 Plymouth Court.

All attending members and guests are invited to join in an informal fellowship dinner. 1.50 per plate.

Dinner 6 to 7 p. m.

Get together recess, 7 to 7:30 p. m.

Friday, January 9, 7:30 p. m.

At City Club, 315 Plymouth Court, 3rd floor.

Constant Potential, Series Distribution for Street Lighting by Chas P. Steinmetz, Consulting Engineer, General Electric Co., Schenectady, N. Y.

Discussion, bringing out experiences with recent modifications of the old standard distribution schemes.

Saturday, January 10, 9:30 a. m.
Inspection trips

(a) Recent Chicago municipal street lighting distribution work, and Northwest Station, Commonwealth Edison Co.

(b) Specially arranged trips by request of members.

FUTURE A. I. E. E. MEETINGS

Midwinter Convention, February 18-20, 1920. The Eighth Midwinter Convention of the Institute will be held in New York, February 18, 19 and 20, 1920. While the details of the program have not yet been completed the tentative arrangements may be summarized as follows:

Wednesday, February 18. The morning will be devoted to registration. In the afternoon members will be permitted a choice between inspection trips to points of engineering interest or attendance at joint session with A. I. M. E. The evening will be occupied by the President's address and presentation of technical papers.

Thursday, February 19. At the morning and afternoon sessions technical papers will be presented under the auspices of various technical committees.

Friday, February 20. On Friday two technical sessions are scheduled for the morning and afternoon. A Dinner-Dance will be held in the evening.

March 12, 1920, Pittsburgh. Meeting under auspices of Traction and Transportation Committee. Subject: Electric Traction.

April 9, 1920, Boston. Joint Meeting with the American Electrochemical Society. Meeting under auspices of Committee on Electrochemistry and Electrometallurgy.

May 21, 1920, New York. Annual business meeting of the Institute.

June 22 to 25, 1920. Annual Convention.

FUTURE SECTION MEETINGS

Boston.—January 6, 1920. Subject: "Electric Welding."

Indianapolis-Lafayette.—January 16, 1920. Joint meeting with other technical societies.

February 20, 1920. Subject: "Problems Confronting Electric Railroads."

Los Angeles.—January 20, 1920. Subject: "Automatic Substations."

February 17, 1920. Subject: "The Engineer in Industry."

Rochester.—January 23, 1920. Paper: "Ignition System" by Mr. Libby, of the Splitdorf Company.

Schenectady.—January 16, 1920. Address by Col. H. M. Waite, of Dayton, Ohio, on "Commission Manager Form of Government."

St. Louis.—January 28, 1920. Technical Story of the Synchronous Converter. Speaker: Mr. B. G. Lamme.

Fort Wayne.—January 15, 1920. Subject: not assigned.

February 19, 1920. Subject: Autogeneous Welding."

March 18, 1920. Subject: not assigned.

A. I. E. E. MEETING, DECEMBER 12, 1919

The 356th regular meeting was held in New York on December 12, 1919 at Institute headquarters, 33 West 39th St. President Townley called the meeting to order at 8:20 p. m. The first paper of the evening "Applicability of Automatic Switching to all Classes of Telephone Service" was presented by the author, Arthur Bessey Smith. He was immediately followed by Ralph Kelley who presented the second paper entitled "The Searchlight in the United States Navy." President Townley then called for a discussion of both papers in which the following men took part: Selby Haar, L. F. Morehouse, W. I. Slichter, Paul S. Clapp, Donald McNicol, F. L. Baer, A. B. Smith, C. A. DeGraaf, M. L. Patterson, E. J. Murphy, J. C. Ledbetter, R. A. Beekman, B. P. Beeler and Ralph Kelley. A number of slides furnished by the Chief of Engineers illustrating types of searchlights used in the Army were shown by Chester Lichtenberg and P. R. Bassett. The meeting adjourned at 11 p. m.

A. I. E. E. DIRECTORS' MEETING DECEMBER 12, 1919

The regular monthly meeting of the Board of Directors of the Institute was held at Institute headquarters, New York, on Friday, December 12, 1919, at 3:00 p. m.

There were present: President Calvert Townley, New York; Past President Comfort A. Adams, New York; Vice-President N. A. Carle, Newark, N. J.; Managers Charles S. Ruffner, Wm. A. Del Mar, W. I. Slichter, L. F. Morehouse, New York, Charles Robbins, Frank D. Newbury, Pittsburgh, Walter A. Hall, West Lynn, Mass., L. E. Imlay, Niagara Falls, N. Y.; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

A report was presented of a meeting of the Board of Examiners held December 8, 1919; and upon the recommendation of the Board the following action was taken upon pending applications: 258 Students were ordered enrolled; 112 applicants were elected to the grade of Associate; 7 applicants were elected to the grade of Member; 5 applicants were transferred to the grade of Member.

Chairman Slichter of the Meetings and Papers Committee reported orally regarding the program for the January 9th meeting in Chicago, and for the Midwinter Convention in New York, February 18-20; also regarding tentative plans for the March meeting in Pittsburgh under the auspices of the Traction and Transportation Committee, and the joint meeting with the Electrochemical Society in Boston in April.

Announcement was made that the January meeting of the Board of Directors will be held in Chicago, on the morning of Friday, January 9.

Upon the recommendation of the Finance Committee, monthly bills amounting to $12,886.49 were approved.

The report was presented of the Joint Conference Committee of the Development Committees of the Founder Societies. In brief, the report recommended the formation of local affiliations, state councils, and a national organization consisting of representatives of local affiliated bodies and national societies. It was voted that the report be endorsed and referred back to the Institute's three representatives on the Joint Conference Committee, for such action in cooperation with the representatives of such other societies as endorse the report as may be necessary to put the recommendations into effect.

The Law Committee presented a report submitting proposed amendments to the constitution providing for the division of the

country into geographical districts and the election of Vice-Presidents therefrom, as recommended by the Development Committee. It was voted that the proposed amendment be approved subject to revision by legal counsel.

A petition for authority to organize a Student Branch at the University of Wisconsin, Madison, Wis., was granted.

In addition to the above, many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the JOURNAL under suitable headings.

EDISON MEDAL AWARDED TO W. L. R. EMMET

At the meeting of the Board of Directors of the American Institute of Electrical Engineers held December 12, the Edison Medal Committee reported that the Edison Medal for the year 1919 had been awarded to Mr. W. L. R. Emmet, "for inventions and developments of electrical apparatus and prime movers." Arrangements will be made for the presentation of the Medal to Mr. Emmet at a convenient later date.

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Mr. Thomas A. Edison, and is awarded annually by a committee consisting of twenty-four members of the American Institute of Electrical Engineers "for meritorious achievement in electrical science, electrical engineering, or the electrical arts."

William LeRoy Emmet, engineer and inventor, was born at Pelham, N. Y., July 10, 1859, son of William Jenkins and Julia Colt (Pierson) Emmet, grandson of Robert and Rosina (Hubley) Emmet, and great-grandson of Thomas Addis Emmet (q.v.), the first one of the family in America. The latter was the distinguished Irish patriot and leader in the Society of United Irishmen in 1798, and an elder brother of the ideal patriot of the Irish race, Robert Emmet, who was executed in Dublin in 1803 Thomas Addis Emmet came to America in 1804 and soon became a leader of the New York bar. His son Robert was a prominent lawyer and judge in New York City.

Mr. Emmet was educated at schools in Canada, New York, and Maryland, and subsequently entered the United States Naval Academy, where he was graduated in 1881. He served as a cadet midshipman until 1883 at Annapolis and on board U. S. S. *Essex*, and re-entered the navy as junior lieutenant in 1898, serving as navigator on the U. S. S. *Justin* during the period of the Spanish war.

His principal civil employment has been with the Sprague Electric Railway and Motor Company and the General Electric Company. He has achieved fame as an electrical engineer and as an inventor, and has obtained many patents for inventions in electricity, mechanics, and thermo-dynamics His most important electrical work has been in the development of the general use of alternating currents and in the invention and design of machinery to further the practical application of alternating currents, while his most important mechanical work has been in connection with the development and introduction of the steam turbine. He designed and directed the development of the Curtis turbine by the General Electric Company, a very large work, every detail of which was radically new, and which was carried on with almost unprecedented rapidity, He designed the machinery for the first ships driven by electric motors; and he was the first serious promoter of electric ship propulsion, conducting a series of experiments with the United States Collier *Jupiter* which are destined to be epoch making.

He is the inventor of several types of transformers, including a form of air-blast type which has been extensively used; of several types of insulation of alternators, and of other details which have met with general acceptance. He is the inventor of the oil switch, a device which is now almost universally used in large electrical work. After experimentally investigating the possibilities at Brooklyn and Niagara Falls, the heaviest circuits then existing, he was the first to design and use switches of this type. The varnished cambric cable which is widely used is also an Emmet invention.

He is the inventor of the vertical shaft steam turbine of which a very large number have been built; and many details of turbine design in general use are to his credit. His achievements have been those of an engineer and a pioneer of new methods rather than those of an inventor and much of his most original and most useful work could not be effectively patented nor perhaps even classified as invention. Most of his work has been connected with operations of the General Electric Company and has been done in close association with other G. E. engineers; and he has made it his special business to find new scope for the talents and facilities which the G. E. organization affords.

Mr. Emmet is the author of "Alternating-Current Wiring and Distribution" (1894) and of numerous important papers presented before the American Institute of Electrical Engineers and other engineering societies. He is a member of the American Philosophical Society, American Institute of Electrical Engineers, American Society of Mechanical Engineers, Society of Naval Architects and Marine Engineers, and of the Naval Consulting Board of the United States. He is also a member of the University and Engineers' Clubs of New York, the Mohawk Golf, Tobique Salmon, Mohawk, Edison, and Schenectady Boat Clubs. He received the degree of D. Sc. from Union College.

NEW YORK SECTION OF A. I. E. E. ORGANIZED

At the November meeting of the Board of Directors of the Institute a petition was presented, signed by more than one hundred members in New York City and vicinity, requesting authority to organize a New York Section, to be conducted under the same general plan as the other thirty-four Sections of the Institute. The Institute's Committee on Development had also recommended that a New York Section be formed.

The question of organizing a New York Section has been discussed from time to time for several years past, but as most of the monthly Institute meetings were held in New York City, the need for a local organization was not so urgent as in the other cities of the country. The growth of the Institute membership and the industrial developments throughout the country make it essential that in order better to fulfill its function as a national organization, an increasing number of meetings of the Institute, in addition to regular Section meetings, must be held in the various cities of the country.

This year, for example, an Institute meeting was held in Philadelphia in October, and others will be held in Chicago, Pittsburgh, and Boston during the months of January, March, and April, and no New York meetings are scheduled during those months. In order, therefore, that the New York members may retain all the advantages of membership it was considered by the petitioners desirable that a local Section be now organized.

The Directors approved the request and a special meeting for the purpose of organizing was held in the Engineering Societies Building, New York, on Wednesday evening, December 10.

The meeting was opened by President Townley, who in a brief address outlined the conditions which, in the opinion of the petitioners and other New York members, make it desirable to organize a New York Section at this time. Mr. Farley Osgood was then elected temporary chairman and presided during the remainder of the meeting.

Proposed by-laws, which had been prepared in advance by Secretary Hutchinson by direction of the President, and which were based upon the by-laws of the existing Sections of the Institute, were then presented and adopted. These by-laws provide that the officers of the Section shall be a chairman, a secre-

tary-treasurer, and an executive committee of five including the above named officers, which committee shall be the governing body of the Section; further, that the officers elected at the organization meeting shall hold office until August 1, 1921, and that officers shall hereafter be regularly elected at the annual meeting of the Section, in June, commencing with 1921.

A nominating committee of five was then appointed and a recess taken, after which, upon the unanimous recommendation of the nominating committee, the following officers were unanimously elected: Chairman, Mr. H. W. Buck; Secretary-Treasurer, Mr. H. A. Pratt; additional members of the Executive Committee, Messrs. E. B. Craft, W. S. Finlay, Jr., and Farley Osgood.

The future activities of the Section were not discussed in detail, but it is understood that the scope of the Section's work will be similar to that of the other thirty-four Institute Sections and it was the general sentiment of those present that the local organization will be decidedly advantageous to the membership of the metropolitan district. By thus organizing, the membership in New York and vicinity are placed upon the same basis in relation to the Institute as the membership in other Section territories.

ADDITIONAL GRADE OF MEMBERSHIP SUGGESTED

The following report of a committee of the Spokane Section, which was approved by the Section at a meeting held November 14, includes the recommendation that an additional grade of membership be established.

As the report was received after the Committee on Development had submitted its recommendations to the Board of Directors, it is published here for the information of the membership. Comments upon the suggestion are invited and should be forwarded to the Secretary of the Institute.

The matter will be considered as one of the topics for discussion by the Section delegates at the next Annual Convention.

REPORT OF A SPECIAL COMMITTEE OF THE SPOKANE SECTION A. I. E. E.

Recommending Changes in Grades of Membership

Your special committee appointed at the last regular meeting to consider the recommendations of the Development Committee and the suggestions resulting therefrom desires to report as follows:

[Note: The opening paragraphs of the report relate to the specific recommendations of the Institute Development Committee and have been referred to the proper committees for consideration.]

This Committee has discussed the present Constitutional requirements as to the grades of membership and dues (the latter having reference to the service furnished to the members by the Institute) and believes the time has come when the Constitution should be amended for the following reasons. Under the Constitution, engineers who have not been in the "active practise of their profession" for five years, but who are, nevertheless, engineers, are placed in the same grade, that of "Associate," with persons who are merely interested in the study or application of electricity and many of the young members believe that they should be in a grade, which would indicate that they are engineers. The present constitutional requirements that Fellows, Members, and Associates shall be equally entitled to all the rights and privileges of the Institute, except as regards holding office, is inequitable. While the policy of admitting engineers just started in the practise of their profession for less admission fee and less annual dues than those who have been in actual practise for five years or more is recognized as good, still the beginners in the profession should be willing to accept a service in keeping with the amount paid for it. Further, after an engineer has been in active practise for over five years he should be able and willing to pay the dues now paid by those of the grade of Member.

As a basis for discussion your committee offers the following suggestions:

There shall be established the grade of "Junior," a "Junior" shall be not less than twenty-one years of age, and shall be either;

(a) An electrical engineer by profession. As such he shall be qualified by experience to fill a subordinate engineering position, or he shall be a graduate in electrical engineering of a school of engineering of recognized standing.

(b) A teacher of electrical subjects.

The requirements for "Associate" (Section 6) shall be amended by eliminating "a" and "b".

The admission fee for "Juniors" and "Associates" shall be $5.00 and the annual dues $10.00.

After a "Junior" has been a member for five years, his annual dues will be $15.00 whether he transfers to the grade of Member or not.

The section of the JOURNAL containing matter relating to *Institute Affairs* and such other matter as shall be added shall be furnished free to those members paying annual dues of $10.00 and the section containing *Institute Papers and Discussion* shall be furnished upon request at cost. All members paying annual dues or $15.00 or over shall be furnished *both sections* free.

The TRANSACTIONS shall be furnished free to all members paying annual dues of $15.00 or over and at cost (average) or less to other members.

The full service of the Institute shall be furnished to Honorary members.

Nov. 14, 1919.

NOMINATIONS FOR INSTITUTE OFFICERS FOR 1920-21

As provided in Section 20 of the Institute By-laws, candidates may now be proposed for nomination for the officers to be filled at the next annual election in May, 1920, by the petition or by the separate endorsement in writing, of not less than fifty members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1920. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: a President and a Treasurer, for the term of one year each, six Vice-Presidents for the term of one year each, and three Managers for the term of four years each.

The Constitution provides that "the President, Vice-Presidents and Managers shall not be eligible for immediate reelection to the same office. A Vice-President shall not be eligible for immediate election to the office of Manager."

For the information of members, the full text of Section 20 of the by-laws, governing the proposal of candidates for nomination, is printed below:

Sec. 20. In addition to the names of incumbents of office, the Secretary shall publish on the "form showing offices to be filled at the ensuing annual election in May" provided for in Article VI of the Constitution, the names, as candidates for nomination, of such members of the INSTITUTE as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than fifty members, received by the Secretary of the INSTITUTE in writing by January 25 of each year; provided, however, that any candidate proposed for nomination by petition may withdraw his name by written communication to the Secretary, and any name so withdrawn prior to the printing of the form shall not be published.

The names of such candidates for nomination shall be grouped

alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each year's JOURNAL, and shall be reproduced on the form above referred to.

ENGINEERING FOUNDATION

MENTAL HYGIENE OF INDUSTRY

FOR about a year Engineering foundation has been supporting researches in the Mental Hygiene of Industry under the guidance of Dr. Elmer E. Southard, of Harvard Medical School, a well-known psychiatrist. He has been assisted by Miss Mary C. Jarrett, a pioneer in psychiatric social work. From a progress report made to the Foundation December 11, the following notes have been taken:

A keynote paper for employment managers has been written by Dr. Southard, entitled "The Movement for a Mental Hygiene of Industry," and several other papers dealing with various phases of this subject are being prepared by Dr. Southard, Miss Jarrett and Miss Butler. The report suggests that the keynote and other papers, after approval by the Foundation's special committee be published in engineering journals and also in such journals as *Mental Hygiene* in order to secure concomittant recognition by medical men.

Miss Jarrett has been laying down lines for special courses to develop employment managers equipped with the new special knowledge. She has interviewed about 20 leading employment managers and has found them very receptive to the idea of supplementary training and of special work in mental hygiene for the employment manager group. She has been able to show that the psychiatrist and the psychiatric social worker are nowadays dealing with mild disorders, tempermental deviations, and slight eccentricities, namely, exactly the kind of thing with which industrial personnel has seriously to deal.

The respective advantages to different sides of the industrial personnel problem have been studied and the results embodied in the Keynote paper submitted to the committee. The psychologist will no doubt prove of greatest advantage in the hiring problem. The psychiatrist will prove to have wider scope in relation to grievances, complaints, dissatisfaction and unrest, so far as these are in part traceable to peculiarities and special conditions in individual workmen. The efforts of the psychiatric social worker will be directed especially to aid in tracing down the discharged cases and the reasons for discharge. The psychiatric social worker will often be able to solve the individual's problem so that that particular employee will not again be a problem for the industry in question, or perhaps for other industries.

NOTES FROM NATIONAL RESEARCH COUNCIL

THE CERAMIC INDUSTRY

The National Research Council and the American Ceramic Society have established a joint committee for promoting the investigation of scientific problems underlying the ceramic industry, especially by founding a series of research fellowships whose holders shall devote their attention exclusively to these problems.

The ceramic industries, including brick and tile making, and general crockery and glass manufacture as well as ornamental potteries, although among the earliest ones developed by man, have been the last of our great manufacturing industries to reach the status of an applied science. They have been based for centuries on rule-of-thumb methods, trade secrets, and individual artistry. As far as their artistic features go science can do little or nothing for them, but in all other ways it can be of great advantage to them and it is certain that an organized effort to develop the fundamental science of ceramics can have a great influence in advancing the industry.

INVESTIGATION OF FATIGUE OF METALS

An investigation of Fatigue Phenomena in metals under repeated stress as announced in the PROCEEDINGS for December, 1919, has just been started under the joint auspices of the National Research Council, Engineering Foundation, and the Engineering Experiment Station of the University of Illinois. The Engineering Foundation is providing $15,000 for two years for this investigation, and the Engineering Division of the National Research Council is acting in an advisory capacity, largely through its committee on Fatigue Phenomena in Metals. The experimental work is being done in the laboratories of the Engineering Experiment Station of the University of Illinois, under the immediate direction of Professor H. F. Moore, Research Professor of Engineering Materials and Chairman of the Committee above mentioned.

Plans are laid for a two years' program of tests, and apparatus and materials are already arriving for the tests. It is hoped to secure a considerable amount of data on tests of various metals including a number of tests of each metal to 100,000,000 reversals of stress. It is hoped to study the various short-time physical tests which are used for metals,—such as the impact test, magnetic analysis, and short-time bending tests,—to see whether any of these tests give reliable indices of the ability of the metal to resist fatigue under millions of repetitions of low stress. It is hoped that some reliable commercial test for this important property may be developed by this investigation.

A test party of four or five persons is being organized and the University of Illinois is fitting up a special laboratory with about 2500 square feet of floor space for the use of this investigation.

CURRENT ENGINEERING TOPICS

CONTINUANCE OF CONSTRUCTION DIVISION

At the time hearings were being held on the subject of Army reorganization the Chairman of National Service Committee of Engineering Council addressed the Military Affairs Committee of both Houses and General Pershing, directing their attention to the splendid record of the Construction Division, and urged that this Division be continued in substantially its present form so that it will be enabled to carry on the work that has been started, in the same efficient manner. Replies from the chairmen of both committees indicated that they realized the value of the Construction Division under its present organization and showed that they personally were in favor of maintaining this Division intact.

There is still a good chance that the Military Affairs committees of both Houses will recognize it as a separate corps. The officials of the Construction Division and practically all civil engineers that have had work with the Division in the various parts of the country desire that such action be taken. It is the general belief that the efficiency of the Construction Division will be impaired if it is returned to the Quartermaster General's Department or made a part of the Engineers Corps.

The points made against incorporating the Construction Division in the Engineers Corps or returning it to the Quartermaster's Department were that the engineers are the first to be sent to the front, whereas the duties of the Construction Division are at training camps, supply depots, etc. at a distance from the actual fighting. Thus it would be far removed from its administration, besides which such men do not have the kind of technical training that is required in the construction work. If the Construction Division was returned to the Quartermaster Depart-

ment it would soon swallow up that Department, especially if the proposed construction program of the Army is carried out.

The bill proposed by the General Staff is dead from a legislative standpoint as is the Dent bill and other drafts made along the lines of the General Staff bill. The Military Affairs committees are drafting entire new Army reorganization bills which it is expected will be introduced in the respective Houses shortly.

ESTIMATES FOR PUBLIC WORKS—FISCAL YEAR 1921

The Secretary of the Treasury has approved and forwarded to Congress estimates for next year which total the unusually large sum of $283,921,810. The appropriations for public works during the fiscal year 1920 total $93,872,092. The estimates for work of particular interest to engineers and constructors are as follows:

Construction of Government buildings, including purchase of sites, $1,332,775; marine hospitals and quarantine stations, $5,204,621; fortifications, $117,793,330; military posts, $14,225,251; rivers and harbors, $53,659,265; navy yards and stations, $20,606,000; Panama Canal construction and maintenance, $18,245,391; depots for coal and other fuels, $2,335,000; Reclamation Service, $20,134,000; $725,000 special appropriation for a fuel inspection system; $1,865,880 for the Bureau of Mines; $2,592,920, Geological Survey; $3,000,000 (approximate), Bureau of Standards.

HIGHWAY LEGISLATION

The original bill proposing to create a National highway system controlled by a Federal Highway Commission, which was proposed by Senator Townsend, has been practically abandoned because of the opposition which has developed. It is now believed that any plan for National highways constructed directly by the Federal Government will be unpopular with the states because only a limited portion of the state will be benefited directly by such highways. Further, the Government with its road building activities would be in competition with the states and the counties. It is believed that it will be easier for the Federal Government to hold the states up to a standard rather than to attempt to maintain the standard through its own work. No plans have been made to secure consideration of the Townsend bill at the present session of Congress.

Another highway bill which proposes a National Highway Department and Highway Commission has been introduced into the House, which aims to do away with the defects which have become apparent in the Townsend bill. It will bring the control of highway work more closely under the control of the states, at the same time giving enough Federal supervision to insure coordination and standardization in the work. The states are to be divided into ten regional areas with corresponding regional congresses having direct control of the work in their region but under the general direction of the National Highway Commission.

For the purpose of carrying out the provisions of this new act and as an initial appropriation for the creation of a National Department of Highways, the new bill proposes to appropriate $10,000,000. The Secretary of Highways would receive $12,000 per year, and each National Highway Commissioner would receive $6,000 per year.

CONVENTION OF NATIONAL DEPARTMENT OF PUBLIC WORKS ASSOCIATION

Willard Hotel, Washington, D. C.
January 13th-14th, 1920

The movement to establish a National Department of Public Works initiated by the technical men of the country, and which took definite form at Chicago last April, is now a live National issue. It is the first National campaign in which the engineers of the United States have united.

The convention announced as above has been called to intensify the interest in the movement, to broaden the scope of the organization, to discuss procedure, and to adapt our activities to the developments that have taken place since last April.

Effort has been made to invite all engineering organizations in the United States but it may be that some have been unintentionally overlooked. The National Public Works Department Association earnestly desires that all such organizations shall regard this announcement as a direct invitation to them to send delegates. All accredited representatives will be heartily welcomed.

The fundamental reason for a Department of Public Works is to secure efficiency and economy in the conduct of Government business. The Secretary of the Treasury recently submitted a $5,000,000,000 budget to cover expenses for the next fiscal year. There are few, if any, proposals in that budget that are not necessary to our general welfare. They will have to be either eliminated or pruned to meet financial limitations, but that process does not constitute a rational solution of the difficulty. We are paying too much for what we get and all measures of economy will be futile until we bring order and organization out of the chaos of our Departmental activities.

INTERNATIONAL ELECTRICAL EXPOSITION FOR SPAIN

According to report of the Bureau of Foreign and Domestic Commerce, Spain is planning for a large international electrical exposition at Barcelona. A permanent exposition is being erected which will probably be completed late in 1920 and the electrical exposition will probably be the first use made of the buildings.

Manufacturers of machinery are to be invited to furnish exhibits in the following groups: Group 1—Generation, transformation and accumulation of energy. Group 2—Transmission and distribution of energy. Group 3—Apparatus and methods of investigation, demonstration and measurement. Group 4—Electric lighting—electricity in the home. Group 5—Application of electricity to the manufacturing industries. Group 6—Application of electricity to traction. Group 7—Telegraphy, telephony and radio-telegraphy. Group 8—Application of electricity to medicine and hygiene. Group 9—Electrochemistry and electrometallurgy. Group 10—Electricity as applied to agriculture. Group 11—Application of electricity to the exploitation of the sub-soil. Group 12—Technical application of electricity.

THE STEEL BASING POINT

As a result of further hearings before the Federal Trade Commission, it has been conceded that there will be no abolition of long established practise of using Pittsburgh as a steel basing point. The interests that favor a single price basing point, notably the Western Association of Rolled Steel Consumers, base their claim on the allegation that Pittsburgh is in violation of the Clayton Act. This group has attempted to show that they pay a fictitious freight rate on fictitious transportation from Pittsburgh on steel produced through the Western district and for this reason they claim that they are unable to compete in the Eastern market, whereas the Eastern fabricators can place their products in the Chicago market on an even competitive basis. They declare that the public was taxed $30,000,000 a year through increased prices of manufactured steel.

Counsel for the Steel Corporation showed that since Chicago producers can only supply one half of the Chicago demand, the Pittsburgh price must dominate since it supplies the other half. There would be no advantage to the Chicago producers in selling at less than the Pittsburgh price when they could not profit by any extra demand so created. They naturally sell at the market price which is the Pittsburgh level. When producers can supply all the requirements of their own territory, the Pittsburgh basing point will cease as a result of natural laws. Other important steel producers have given testimony substantiating these claims.

AIRCRAFT STATISTICS IN THE NAVY

A very comprehensive report has been submitted by the Secretary of Navy covering activities through November 1st, 1919. This report shows the number, type and cost of all aircraft built, building, and under contract to be built, the number of and type of aircraft to be constructed in Government plants, for which material has been delivered or ordered.

The report contains details of facilities of every kind maintained wholly or in part by the U. S. Navy for procuring producing, inflating, operating, preserving and handling aircraft. This includes active and abandoned operations and covers the connection of each of the Navy bureaus with the operation in question. This report was prepared in response to an order from the Committee on Naval Affairs.

TECHNICAL WORK AT THE BUREAU OF STANDARDS

Bulletins on the progress of experimental work that has been started at the Bureau of Standards are as follows:—1. Radio Fog Signalling Experiments. 2. Standardization of Electron Tube Symbols. 3. Scientific Research on Electron Tube Amplifiers. 4. Magnetic Analysis. 5. Industrial Safety Standards. 6. Photoelectric Spectrophotometry. 7. Reinforced Conc ete Investigation. 8. Durability of Cement Drain Tile in Alkali Soil. 9. Investigation of Concrete Tanks for the Storage of Oil. 10. The Effect of Protective Coatings on the Strength of Manila Rope. 11. Investigation of Oxyacetylene Welding and Cutting Apparatus. 12. Strain Gage Measurements of 350-Ton Crane. 13. Locomotive Packing Ring Investigation. 14. Embrittlement of Lead by Corrosion and Its Relation to the So-Called Allotropy of Lead. 15. Weights and Measures Publications. 16. Assistance in Graduating of Anthropometric Instruments. 17. Graduation of Saccharimeter Scales for a Large Sugar Concern. 18. Testing of Hydrometers. 19. Meeting of Committee on Paper Specifications. 20. Investigation of Thermostatic Return Line Valves for Heating Systems.

Because of the current nature of these investigations the results are not generally put in printed form but complete data on the results of the work to date are always available on application to the Bureau of Standards or the National Service Committee in the Washington office of Engineering Council.

BOSTON-WASHINGTON SUPER POWER LINE

The following is a copy of letter which was sent to all organizations which are located within the Boston-Washington survey.

Because of the vital importance of this subject to all branches of the engineering profession, Engineering Council has urged that it be given careful consideration and support of engineering organizations and their individual membership throughout the interested districts.

It is a special note-worthy fact that in addition to inquiries from interested engineers within the districts that will be covered by the survey a number of inquiries have been received from engineers throughout the West and Middle West concerning this project.

It is especially an engineering project and needs the active support of the engineering profession.

INDUSTRIAL SAFETY CODE CONFERENCE*

A conference on Industrial Safety Codes was held at the Bureau of Standards, Washington, D. C., on December 8, 1919. In the absence from Washington of the Director of the Bureau, Dr. S. W. Stratton, the meeting was called to order by Dr. E. B. Rosa, who summarized the events leading up to this conference and referred especially to the proceedings of the similar conference held on January 15th, of which this in a sense was an adjourned meeting. The principal subjects which came up at the January conference were the reorganization of the American Engineering Standards Committee, and the question of whether the safety work of the Bureau of Standards should be conducted under the scheme of procedure laid down by that committee.

The last question was the subject of a letter ballot sent out in the spring, the result of which was a decided majority in favor of procedure under the plan of the American Engineering Standards Committee. This Committee has adopted since the January conference a revised constitution which opens its membership to other organizations in addition to the original five founder societies and three Government departments.

Dr. Rosa also announced the appointment of a General Advisory Committee on Industrial Safety Codes for the purpose of assisting the Bureau of Standards in deciding upon policies and procedure in its work on safety codes. He said: "The Advisory Committee recently appointed by the Bureau is not a managing committee. It is for the present merely an advisory committee for the Bureau of Standards."

Prof. Comfort A. Adams, Chairman of the American Engineering Standards Committee, then spoke on the work of that Committee and its recent reorganization. Membership in the Committee is now open to such organizations or groups of organizations of national scope as may be approved. The speaker stated that he would be superseded as Chairman of the Committee by Mr. A. A. Stevenson, and that the permanent Secretary of the Committee will be Dr. P. G. Agnew, at present in the Bureau of Standards. The headquarters of the Committee will be in New York City.

The procedure to be followed in the development and adoption of American Engineering Standards was then outlined. Committees to formulate standards shall be organized by suitable engineering societies, Government Bureaus or other bodies which shall be designated as sponsors and shall be responsible for the carrying out of the work. Such a Committee must include representatives of all interests concerned in the formulation of a standard, and upon completion of its work and substantial agreement upon the same, shall report to the sponsor body. If the latter adopts the standard it is forwarded to the American Engineering Standards Committee for approval, and when so aproved, shall be designated as either Recommended Practise, Tentative Standard, or American Standard. The Standards Committee will not itself pass judgment upon the details of the proposed standards but rather upon the composition of the Committee which has formulated the Standard or approved it. This Committee must not be confined to the membership of the sponsor body, but must include representatives of all interests concerned in the standard.

The status of industrial safety codes now existing was next discussed. Dr. Lloyd exhibited a number of charts on which it was attempted to show the scope of existing safety rules in the industrial field but exclusive of the subjects of transportation, mining and industrial hygiene. The relation of fire prevention to human safety was considered.

Dr. Chaney pointed out that a survey of accident records would show what hazards are greatest and consequently what industries are most in need of safety regulations. The method of administration of safety rules is of more importance than the contents of the rules themselves. Compensation laws have brought about an improvement in accident prevention work.

Mr. Collette referred particularly to the Boiler Code of the American Society of Mechanical Engineers and the recent work of that society in preparing an Elevator Code in cooperation with the Bureau of Standards.

Mr. Paine referred to the disadvantages of non-uniformity and of temporary rules and said that to have a satisfactory code it was necessary to have the cooperation of all interested.

The symposium on Methods and Policies to be Pursued in the Development and Introduction into use of Safety Standards was then presented.

The following resolution which was proposed and adopted by the Conference:

Resolved: (1) That the American Engineering Standards Committee be asked to request the International Association of Industrial Accident Boards and Commissions, the Bureau of Standards and the National Safety Council to organize a Joint Committee on Safety Codes, this committee to include representatives of these bodies and such others as they may consider advisable: (2) that this Joint Committee report upon the Safety Codes required, priority of consideration of the codes, and sponsor bodies for their preparation; (3) that this report be put in writing and placed not later than February 1, 1920, in the hands of the American Engineering Standards Committee.

Before taking the vote on this, however, another motion was passed confirming the result of the letter ballot taken last spring and expressing the decision of the conference that Safety Codes should be established under the procedure of the American Engineering Standards Committee.

It was pointed out that the American Engineering Standards Committee was not primarily interested in safety matters and that the Committee contemplated in the above resolution would be directly concerned in such matters and might well serve as a steering committee on safety code work. The opinion was freely expressed that such a committee should be a permanent one, that it should contain representatives of all interests involved in safety codes.

At a meeting of the General Advisory Committee of the Bureau on the following day the work of the proposed committee was further discussed and the opinion was generally expressed that such a committee, if made a permanent organization, would render the General Advisory Committee of the Bureau of Standards unnecessary.

INSTITUTE REPRESENTATIVES

The Institute, together with other national engineering societies, is represented upon a considerable number of committees, commissions, and other organizations formed for the purpose of cooperation upon matters of common interest. The terms of a number of these representatives have expired or are about to expire, and at the meeting of the Board of Directors held December 12, action was taken as follows:

United Engineering Society, Board of Trustees: Mr. Calvert Townley, whose term expires in January, was reappointed for a term of three years. The hold-over Institute representatives are Messrs. L. T. Robinson and Samuel Sheldon.

Engineering Council; Mr. H. W. Buck was reappointed and Mr. Charles S. Ruffner appointed, for terms of three years each commencing in February 1920. The hold-over representatives are Messrs. N. A. Carle, C. E. Skinner, and C. A. Adams.

Library Board, United Engineering Society: Mr. Edward D. Adams was reappointed for a term of four years commencing in January 1920. The hold-over representatives are Messrs. Samuel Sheldon, W. I. Slichter, A. W. Kiddle, and F. L. Hutchinson.

American Engineering Standards Committee; Mr. C. E. Skinner was appointed for a term of three years commencing in January 1920. The hold-over representatives of the Institute are Messrs. C. A. Adams and H. M. Hobart.

Commission of Washington Award: Professor Charles F. Scott was reappointed for a term of two years commencing in January 1920. The other representative of the Institute is Lieutenant-Colonel John Price Jackson.

A NEW WELDING PUBLICATION

The initial number of the *Journal* of the American Welding Society has made its appearance under date of October, 1919. It is published by the American Welding Society at 33 West 39th Street, New York, and is the official organ of the American Bureau of Welding in which a large number of technical societies and organizations is represented. The *Journal* presents a handsome typographical appearance and contains much valuable technical information on the art of welding. Welding has not developed as it should, for lack of a source of authentic information, which the new publication bids fair to supply.

PERSONAL

Manuel Cruzat, in conjunction with others, has formed the South American Translation Bureau, which will handle consulting work in regard to South American trade, and also advertising and technical translations, with the purpose of cooperating with the engineers, business men and manufacturers of the United States. The Bureau has opened an office at the Grand Central Palace, New York City.

George M. Brill announces that following an interruption of his consulting practise in Chicago including two years of war work he has resumed his practise in New York.

He will continue to specialize in the engineering of industrial plants and processes, improvements in operation and financial investigations. A temporary office has been opened in the Singer Building, New York, but after May 1st he will move into permanent quarters at the Guarantee Fifth Avenue Building.

Major John J. McConnell, former United States Constructing Quartermaster and Utilities Officer in the Construction Division of the Army, has been discharged from the Service, and is now located in Room 602, Commercial Bank Building, Alexandria, Louisiana, and will engage in a general contracting and engineering practise.

Gustav Hirsch, formerly Lieut. Colonel in the Signal Corps, has resumed a general consulting practise with offices at the Hartman Building, Columbus, Ohio. During his service he was division signal officer of the Thirty-Sixth Division, ten months of this service being in France.

Mr. M. C. Henderson, City Electrical Engineer of Dunedin, New Zealand, was a visitor at Institute headquarters on November 26.

Mr. Henderson while in the United States is visiting a number of the principal electrical manufacturing and operating companies.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities, is given below, together with the addresses as they now appear in the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

Lieut. Chas. H. Arnold, 1016 Myrtle Ave., Erie, Pa.
Robert F. Arnott, Amer. District Steam Co., No. Tonawanda, N. Y.
Jason L. Frye, Camp Kearny, Cal.
Colonel B. B. Hyer, Camp Wheeler, Macon, Ga.
Henry D. Lindsay, 232 Prospect Ave., Milwaukee, Wis.
Major Geo. C. Oxer, Florence, Ala.
Wm. A. Street, Gatun, C. Z.

The Committee on Classification and Compensation of Engineers presented to Engineering Council December 18, an interesting Progress Report which contained a proposed classification for engineers in federal, state, county, municipal and railway employment. This classification will be published in the near future. Adoption and use of a suitable classification of engineers throughout the country is fundmaental to intelligent consideration of compensation for various engineers, especially in Governmental employment, city, state and national.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months. during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

SERVICES AVAILABLE

ADVERTISING OR SALES connection in New York or metropolitan district, will be considered by commercial engineer. Twelve years successful experience in consulting, contracting, buying, selling, editorial writing and technical advertising. Expert in mechanical, steam and electrical equipment, wiring and piping for buildings and power plants. Exceptional ability, backed by common sense, initiative and ready adaptability to new conditions. Salary $4000. Salary and commission or bonus, considered. E-2001.

CONSULTING ENGINEER open for engagement to Utility or Industrial Concerns. 15 years superintendent construction and operation. 8 years consulting and designing industrial, power, railway and lighting systems. Efficiency engineer and fuel combustion expert. Rates and valuation. E. E. and M. E. Degrees. Minimum salary $6000. Correspondence solicited. East preferred. E-2002.

ELECTRICAL ENGINEER; technical graduate, with two years modern mechanical and marine engineering, two years manufacturing and six years commercial and efficiency engineering experience; also considerable experience in industrial haulage and handling of materials in large manufcturing establishments. Desires to locate in New York City, or vicinity. Single, age 33. Salary about $3000. E-2003.

ELECTRICAL ENGINEER, A.B. and E.E.; seven years experience with a large manufacturer of telephone apparatus; 8 years head of department of electrical engineering in a state university; has done much work of the Dean; desires teaching or commercial position. Minimum salary $4000. Salary scale too low at present location. E-2004.

ELECTRICAL ENGINEER; M. I. T. 1915; age 27, married; principal experience in engineering department, public utility; on central station design, office records, and data; qualified for an executive position. Excellent personality, energetic, initiative and will get results. Prefer New England or vicinity. Salary $3000. E-2005.

ELECTRICAL ENGINEER; technical graduate; ten years experience in design of electric control apparatus; eight years on staff of one of largest manufacturers of control equipment; two years assistant to consulting electrical engineer. Has handled estimates, specifications and engineering correspondence. Location immaterial. Age 38, married. Salary $3600. E-2006.

ELECTRICAL ENGINEER; technical graduate; age 26, ex-army officer; 2½ years practical experience; familiar with operation, installation, and testing of storage batteries, gas engines, rectifiers, motors, generators etc.; experienced in design of electrical circuits, power boards, etc.; desires position where initiative and ability count. Available immediately. E-2007.

ELECTRICAL ENGINEER; technical graduate, age 25. G. E. Test, Schenectady, Pittsfield and Lynn; experienced in modern shop manufacturing and production methods; familiar with textile industry; desires position in or near New England in either Sales or Industrial Engineering. E-2008.

ELECTRICAL ENGINEER college graduate, 28 years of age; experience in design and test of direct current motors and generators; short experience in power plant work and teaching, desires a permanent position where experience would be of practical use. E-2009.

ELECTRICAL ENGINEER desires position in Eastern Ontario, Canada; at present chief electrician large by-product coke plant. Ten years general steel mill construction and operating experience. Thorough knowledge of motor repair work A. C. & D. C.; and magnetic control. Ability to handle men; also to specify and purchase electrical equipment. Salary $3000. E-2010.

EX-ARMY OFFICER WANTS position as assistant manager or Commercial Engineer with Electric Light and Power Co. Capable of getting and holding business. Experienced in sales, power application, operating and construction. Salary $3600, to start. E-2011.

EXECUTIVE ENGINEER desires position as manager or superintendent of construction of electric light or railway properties, or as appraisal engineer on the valuation of public utilities or private plant. First class references backed by years of experience in the above lines. Minimum salary $3000 per year. E-2012.

GRADUATE ELECTRICAL ENGINEER, three years operating, testing, and maintenance of electrical distribution and machinery, one year light and power salesman; desires position where energy and ability will produce additional responsibilities. Age 25. Salary to start $1800. E-2013.

GRADUATE ELECTRICAL ENGINEER, American, age 30. Nine years experience steam electric power house construction, design and operation. Familiar with high tension, piping and steel layouts. Recently discharged from Army. Desires position in East. Available at once. Salary $2700. E-2014.

INDUSTRIAL-ELECTRICAL ENGINEER; 10 years experience in design, construction and operation of steel and industrial plants. Capable of assuming responsible charge of work. Married. Available immediately. E-2015.

MECHANICAL AND ELECTRICAL ENGINEER; Graduate, age 32; machinist by trade; five years general industrial experience, three years sales engineer with large oil company. Officers' Radio School, Columbia University, N. Y. Position desired in N. Y. or Pa. Can give best of references. E-2016.

PRACTICAL ELECTRICAL ENGINEER and construction man. Yale graduate. Married. Age 29. 5 years on station operating and construction 2 years on building construction and appraisal; and 2 years in charge of station design. Wishes position as Superintendent of Construction or Design Engineer. Salary $3000. E-2017.

PRODUCTION, MECHANICAL AND ELECTRICAL ENGINEER; technical graduate, practical experience from small jobbing to large manufacturing concerns. Modern methods of scheduling, planning, routing and controlling the production, payroll, distribution, cost and stores-keeping. Now production manager of large concern. Just installed and organized a system for above. Climate not agreeable. E-2018.

TECHNICAL MAN, age 23, 3 years college training in electrical engineering, two years experience on house wiring, two years electrical testing, for past 18 months assistant engineer in electrical construction division of large electric railroad. Minimum salary $1800. E-2019.

YOUNG ELECTRICAL ENGINEER desires position in medium sized industrial power plant to have charge of operating, care and maintenance. 7 years experience on A. C. & D. C. equipment of all kinds. Assoc. A. I. E. E. and member N. A. S. E. Age 22. Location preferred south or west. E-2020.

TECHNICAL GRADUATE; age 38, single, member; seventeen years experience design, operation and construction of central stations. At present with public utility company operating a number of electric light and ice plants. Will go any where. Salary six to eight thousand dollars per year depending on location. E-2021.

ELECTRICAL ENGINEER; university graduate; age 32; experience in design of power plants and substations, also in general engineering work and possessing executive and initiative abilities, would consider any proposition offered in New York City or its close vicinity. E-2022.

Electrical Engineer, age 36, technical graduate; twelve years experience with large hydro-electric company, covering nearly all phases of public utility service. Now in charge of all transmission and distribution lines and sub-stations. Desires position as superintendent. Energetic and good executive; good personality. E-2023.

Draftsman; five years electrical and mechanical experience, including plant layout work. Desires permanent position where initiative and ability are considered an asset. E-2024.

Electrical Engineering Graduate, age 24, desires position with small growing hydroelectric power concern in the Northwest. Experience in preliminary surveys, power calculations, etc. Was in charge of responsible engineering work in army as 1st Lieut. in Air Service. Available immediately. Salary $150. E-2025.

Graduate Electrical Engineer: Associate; age 27; married; three years practical experience in power plant, and sub-station designing; specialist on switch-board design and manufacture. One year Westinghouse apprentice. Position desired requiring executive ability. At present in employ of large Eastern electrical manufacturer. Middle West location preferred. Salary $3000. E-2026.

Electrical Engineer, technical graduate, age 25; desires position in station betterment and power development work, or with reliable consulting engineering firm. Approximately two years Westinghouse test and one year in engineering department, with responsible positions in both. Also some central station experience. References if wanted. Salary $2300. E-2027.

Electrical Engineering graduate, 1919, with degree of B.S. age 22, desires a position leading to experience in design or use of electrical machinery in industry or electric traction. Would also accept position with concern furnishing electric power. Have two years experience in testing d-c. machinery. Salary $30 per week. E-2028.

Electrical Engineering graduate, 1917; degree of B. S.; desires position with concern manufacturing electrical apparatus, which will lead to sales; would consider position with public utility corporation; several years varied experience in operating and testing electrical machinery. Location New York City or vicinity. Salary $30 per week. E-2029.

OPPORTUNITIES

University of Wisconsin, Electrical Engineering Department, desires to appoint before February an assistant or associate Professor of Electrical Engineering qualified to assume charge of the Central Station and Electric Railway Courses. An experienced engineer who has carried on investigative work resulting in contributions to the art is desired. R-2080.

University of Wisconsin, Electrical Engineering Department, will appoint in February an instructor in electrical engineering. Salary $1500-1800. for nine months school year. A man with an unusually thorough grasp of fundamental electrical theory and a few years of experience in the engineering or teaching field is desired. R-2081.

Efficiency Engineer, experienced in time study and rate setting. Location Cleveland, Ohio. R-2150.

Electrical Engineer Graduate with 1 to 3 years experience in meter, motor and miscellaneous testing, to organize and develop a meter and test department and assume full responsibility for the testing, calibration and proper operation of meters and relays in a large hydro-electric plant and a large Rotary Converter Sub-station; also to make motor and other tests in a large industrial plant. Good opportunity for a man with initiative and resourcefulness. Reply stating education, experience and salary expected. Location New York State. R-2152.

Electrical Tester, trade school or technical school graduate with some experience in testing all classes of A.C. and D.C. meters and A.C. and D.C. motors; to act as an assistant in the electrical testing department, duties of which are outlined above. Location New York State. Salary $90-120 per month. R-2153.

Designer & Detailer for Electric Traveling Cranes, with several years experience and familiarity with both mechanical and structural features. Opportunity for capable man to develop rapidly to chief draftsman. Location Pennsylvania. R-2161A.

Associate in Export Work; must be either electrical or mechanical engineering graduate; with considerable experience in power plant and electrical lines. Would be given an opportunity to take a $20,000 interest in the corporation and would be given charge of one of the offices in China. R-2171.

Chief Draftsman, technical education, and three or four years shop or drafting room experience on engine and boiler work. Location Cincinnati, Ohio R-2174.

Instructor in Engineering Mechanics, must have technical education. Department is being reorganized; good opportunity for the right man. Must report by February 1st, 1920. Location Connecticut. Salary $1500-1800 per year. R-2181.

Engineering Accountant capable of handling complete report work and distribution of labor and materials reports. Should have some practical knowledge of railroad work, both in the field and office and a good understanding of Interstate Commerce construction accounts. Two Openings. Location Middle West. Salary $175.00. R-2188.

Inspector of Engines and Turbines must have had practical experience in steam power plants. Technical graduate desired. Location Hartford, Conn. R-2194.

Electrical Engineers; technical graduates with one or two years experience, also recent graduates, for work in telephony. Location New York City. R-2197.

Engineer Executive to take charge of the design, construction, and installation of all machinery for four wireless stations of not more than 240 miles range. Location vicinity of New York. R-2207.

Assistant Professor of Electrical Engineering; several years of teaching experience. Duties will consist of class room and laboratory work, chiefly in electrical engineering, and including some work in physics. Location Baltimore District. Salary $2400 per year. R-2210.

Storeroom Executive capable of planning, directing and supervising all activities pertaining to automobile stores management in an operating organization and also in an automobile factory. Location Chicago, Ill. R-2213.

Power Salesman; graduate electrical engineer with at least four years experience in general electrical work. Permanent position. Good future. Location Easton, Pa. Salary $175-200 per month. R-2233.

Technical Translator must understand either French, Spanish or Portugese. Position is in editorial department of a large publishing house. Several openings. Location New York City. R-2235.

Electrical Draftsman for work on electrical design of generating and sub-stations. Experience in this work while desirable is not absolutely essential. Several Openings. Location Chicago, Ill. Salary $110-140 per month. R-2239.

Chief Draftsman; must be familiar with general machine design, and big and broad enough to handle problems of power and plant engineering. Office now employes about ten men. Excellent opportunity for future advancement. Location Massachusetts. R-2262.

Sales Engineer for special power plant auxiliary equipment. Headquarters at New York City. R-2268.

Assistant Engineer with mechanical and electrical experience for design, experimental and research work. Marine experience would be useful. Location Massachusetts. R-2269.

An Ambitious Man with about three or four years experience in designing of commercial electric motors, also specifications and production methods in manufacturing. Location Maryland. R-2273.

Draftsman, for Plant Engineering Division of Industrial concern; *Architectural*, experienced on reinforced concrete and steel building. *Electrical*, familiar with lighting and power layouts. *Pipe*, able to lay out service and hot water piping. *Mechanical*, general experience. Salaries in accordance with ability. Location, Conn. R-2285.

Instructor in Electrical Engineering in a Western University. Two years practical experience desirable; can begin duties at once. R-2288.

Chemical, Electrical & Mechanical Engineers, recent graduates, for work in lamp development laboratory. Openings for 8 or 10 men. Location New Jersey. R-2297.

Translator, Electrical Engineer preferred, who can rewrite French technical information into English. One who has received his education in France would naturally be preferred, but, it is not essential. Location New York State. R-2300.

YOUNG ELECTRICAL ENGINEER with industrial experience and some teaching ability for a teaching position that will pay from eighteen to twenty-one hundred dollars at the start; should be the kind of man who can get along with boys and influence them properly. Location St. Louis, Mo. R-2301.

RESEARCH ASSISTANT for University Engineering Experiment Station. Graduate study in Electrical Engineering, or experience in research essential. Location Illinois. R-2302.

MECHANICAL OR ELECTRICAL DRAFTSMAN for electrical heating appliances. Location New York City. R-2305.

INSTRUCTOR IN MECHANICS at a Middle Western University for next semester, beginning about February 10th. Salary will depend on qualifications; maximum $1900 for academic year. R-2310.

ENGINEER with broad experience in various industries for editing technical publications. Location South New England. R-2315.

ELECTRICAL DRAFTSMEN wanted who are familiar with electrical layouts for general industrial plant work and who also have a good knowledge of mechanical drafting. R-2324.

YOUNG GRADUATE IN ELECTRICAL ENGINEERING COURSE for valuation of telephone public utilities. Applicant must have had telephone engineering experience. Salary $125 to $150 per month and traveling expenses. Location Illinois. R-2329.

FIVE (5) YOUNG ENGINEERS interested in power house and sub-station work to lay out electrical circuits. This is a particularly good opening for men who have not finished their technical course. Permanent positions with unusual opportunities for advancement. Location Western Pennsylvania. R-2330.

MECHANICAL DRAFTSMAN wanted by well-established company, manufacturing a complete line of D.C. and A.C. generators and motors. Good opportunity for experienced man who is capable of working into position of assistant chief draftsman. Location Western Penn. R-2332.

OFFICE MANAGER for a manufacturing concern. Will have charge of all the clerical forces with the exception of those pertaining directly to the purchasing and selling departments, and also of the accounting, financial reports, credits, collections, etc. To qualify, applicant must be able to handle clerical forces and must be thoroughly posted on all matters pertaining to accounting and costs, as well as taxation. Salary $4000 per year up. Location Massachusetts. R-2342.

SALES ENGINEER to handle line of boilers, engines, power plant machinery and electric traveling cranes and hoists in New York City territory. R-2346.

INSTRUCTORS with practical experience in telephone and telegraph work, to teach fundamentals of Electricity four days and evenings. Two openings. Salary $25 per week and bonus end of year. Location New York City. R-2378.

ENGINEERS, ESTIMATORS, DRAFTSMEN AND INSPECTORS on laying out and inspecting underground and overhead distribution lines. R-2386.

OFFICE EXECUTIVE; must be high grade man thoroughly conversant with time, stock and cost records, familiar with accounting and experienced, if possible, in buying and selling. Location Michigan. R-2402.

ENGINEER with 3 or 4 years experience since graduation for testing laboratory. Work will be special investigations involving laboratory research work and also factory testing of electrical apparatus. Applicant must be above average in alternating current theory and must have had experience in test department of a large manufacturer. Laboratory experience in electrical measurements desirable. Location New York City. R-2403.

ELECTRICAL ENGINEER OR PHYSICISTS especially interested in illumination or photometry. Openings also for chemical engineers in research work. Positions are with a government bureau. Recent graduates considered. Salary $1200 per year and up. R-2404.

YOUNG ENGINEER of sound technical training desired in connection with the development of new high frequency electrical apparatus. Good grasp of physical and mathematical fundamentals important. Signal Corps experience useful. Permanency assured. Give details of training, experience and salary desired. Location New York City. R-2405.

JUNIOR RESEARCH ENGINEER; a long established industrial organization in a rapidly expanding field has an attractive opportunity for a young man of first-class ability and thorough training in electrical engineering or technical physics. Post graduate training desirable but not insisted upon. Prospects limited only by ability. Salary proportionate to education and record. Location New York City. R-2406.

DEVELOPMENT ENGINEER; young engineering graduate wanted for experimental development work on electrical apparatus. Distinctive opportunity for young man of energy, resourcefulness and supervisory capacity to grow with new engineering developments of a fundamental nature. Salary determined by qualifications. Location New York City. R-2407.

RECENT GRADUATES for statistical work. Salary $25 per week. Location New York City. R-2416.

ELECTRICAL ENGINEER now engaged in practical work to assist in dynamo and testing laboratories Monday and Tuesday evenings each week. Technical graduate with a few years of experience and familiar with electrical machinery desired. Position is with an educational institution. Teaching experience unnecessary. Salary $3-3.50 per evening. Location Brooklyn, N. Y. R-2419.

RECENT ELECTRICAL ENGINEERING GRADUATE for sales and export work. Location New York City. R-2420.

EDITOR.—Technically educated man with editorial experience, initiative, and judgment, for position of responsibility with long established high grade engineering periodical. Replies should include the essential facts. R-2424.

ELECTRICAL FOREMAN for Construction Department of Power Company; must be capable of taking entire charge, under supervision of Electrical Superintendent of crew of five or six men, in connection with rebuilding of 18,000 K. W. central station bus structure and switch board. Technical graduate preferred although man with practical experience will be given due consideration. Initial salary $140 per month with opportunity for advancement. Application should contain detail information concerning technical training, past experience, age, nationality, attitude towards question of organized labor and whether or not applicant is user of intoxicating liquors. R-2425.

DRAFTSMAN wanted to lay out construction plans and mechanical equipment for large power houses, apply Westcott & Mapes, Inc., 207 Orange St., New Haven Conn., R-2427.

INSTRUCTORS; All engineers, who are willing to consider teaching positions, are invited to register with the Engineering Societies Employment Bureau. The Bureau has been called upon to fill more positions, varying in grade from Laboratory assistant to heads of department in the various engineering and technical schools of this country, than it has been able to do from among the men now registered. Blanks for the purpose of registration and information regarding the Bureau may be had by addressing W. V. Brown, Manager, 29 West 39th Street.

On the subject of "Payment for Estimating" Engineering Council has appointed three conferees: T. L. Condron, Ralph Modjeski and S. G. Neiler, who are collaborating with an equal number of representatives each of the American Institute of Architects and the Associated General Contractors of America.

As a temporary expedient Engineering Council recently mailed to 50,000 engineers an appeal for funds for carrying on its work. This extraordinary measure was necessitated by present financial conditions resulting from the war. Engineers are expecting much of Council and commending the work which it has done. In order, however, that Council may continue its work for professional welfare and civic service, not less than $45,000 are needed for the year 1920. Of this amount, $30,000, at least, must come from general contributions. To December 16, 550 contributions have been received, totaling $3843. They range from one dollar to $100. each, and average $7.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES FROM NOV. 1st—NOV. 30th, 1919

Unless otherwise specified, books in this list have been presented by the publishers. The Library does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

THE ANALYSIS OF MINERALS AND ORES OF THE RARER ELEMENTS.

For Analytical Chemists, Metallurgists, and Advanced Students. By W. R. Schoeller, and A. R. Powell. Lond., Charles Griffin & Co., Ltd.; Phila., J. B. Lippincott Co. 1919. 239 pp., tables, 9 x 6 in., cloth., 16 shillings. (Gift of J. B. Lippincott Co.)

This is a practical laboratory guide for those interested in the determination of the so-called rare elements, and is the first work, the authors state, in which the complete analysis of the minerals of these elements has received systematic treatment. The methods have been selected from various authorities, supplemented when necessary by methods devised by the authors. Full details are given in each case.

ASBESTOS—From Mine to Finished Product.

N. Y., Asbestos and Mineral Corporation. 1919. 194 pp., 60 pl., 11 x 10 in., cloth.

A collection of sixty photographs of asbestos minerals, mines and manufacturing plants, forming a pictorial presentation of the mining of raw asbestos and its manufacture into finished goods. Brief explanatory notes accompany the illustrations.

HAND-BOOK OF FIRE PROTECTION.

By Everett U. Crosby, Henry A. Fiske and H. Walter Forster. 6th edit. N. Y., D. Van Nostrand Company, 1919. 757 pp., illus., tables, 7 x 5 in., flexible cloth, $4.

This work has long been a standard reference book for insurance engineers and inspectors, in which those methods of fire protection which have crystallized into good practise are collected and presented concisely. The present edition has been enlarged by new chapters and illustrations, and has been carefully revised.

THE OUTLOOK FOR RESEARCH AND INVENTION.

With an Appendix of Problems Awaiting Solution. By Nevil Monroe Hopkins. N. Y., D. Van Nostrand Company, 1919. 241 pp., 1 pl., 6 por., 8 x 5 in., cloth, $2.

The object of this book is to stimulate a more general interest in American research, to indicate its necessity at this time, to explain the educational requirements for research workers and to point out the ways in which such work is done inefficiently at present. Appended to the volume is a list of suggested lines of research.

THE STRATEGY OF MINERALS.

A Study of the Mineral Factor in the World Position of America in War and in Peace.

Edited by George Otis Smith, with an introduction by Franklin K. Lane, N. Y. & Lond., D. Appleton & Co., 1919. 372 pp., 8 x 5 in., ½ cloth, $2.50.

CONTENTS: International Relations and Economic Minerals—The Shipping Crisis—Mineral Fuels—Tendencies of Power Production—Iron and Its Associates—Copper—Lead and Zinc—Minor Metals—Minerals in the Chemical Industries—Other Industrial Minerals—Position of the United States among the Nations—A Case of National Dependence: Germany—A Look Ahead—War-time Control of Minerals.

The part played by minerals in the World War and their share in reconstruction are discussed in this volume by a group of geologists in the Government service. The strategic value of mineral resources of the United States in the larger reorganization of peace is taken up along with the problems of their utilization and conservation.

TRAITÉ DE MÉCANIQUE RATIONNELLE.

By Paul Appell. 4th edit., vol. 1. Statique—Dynamique du Point. Paris. Gauthier-Villars et Cie. 1919, 619 pp., 10 x 7 in., paper, 36 francs.

The treatise of which this book forms the first volume is a comprehensive one, covering the course given for many years in the Faculté des Sciences of Paris. The first volume includes the theory of vectors, statics, and the dynamics of particles. The present edition has been thoroughly revised and references to recent writings on the subject have been added.

No previous knowledge of mechanics is assumed. The work is designed to give a thorough understanding of present knowledge of mechanics to those studying the subject in preparation for an engineering career.

A TREATISE ON GYROSTATICS AND ROTATIONAL MOTION. THEORY AND APPLICATIONS.

By Andrew Gray. Lond., Macmillan & Co., Ltd. 1918. 530 pp., illus., tables, 10 x 7 in., cloth, 42 shillings. (Purchase).

Professor Gray has tried to supply a systematic discussion of gyrostatic action and rotational motion which will be of use both to students of dynamics and to practical men. To many engineers, the gyrostatic action of machinery is more or less of a mystery, while to the student, gyrostatics is an affair of certain formal equations by means of which certain elementary results can be obtained.

In the present work, a large number of gyrostatic problems of actual apparatus are discussed, each being referred to first principles and the solutions derived by steps which can be interpreted at every stage of progress.

PAST SECTION MEETINGS

Atlanta.—November 10, 1919, Chamber of Commerce Hall. Address by Chairman A. M. Schoen on activities and aims of the United Engineering Council. The subject of greatest interest was the proposed draft of a bill by the United Engineers' Council which was designed to regulate the practise of engineering in the United States and Canada.

Boston.—November 12, 1919, Engineers Club. Paper: "Storage Batteries, Their Many Applications and Methods of Operation." Speaker: J. Lester Woodbridge. Attendance 100.

Chicago.—September 30, 1919, Fullerton Hall. Subject: "City Zoning." Speaker: Robert W. Whitton, City Plan Commission, Cleveland, Ohio. This was a joint meeting with the General Committee Technical Societies of Chicago. Attendance 250.

October 21, 1919, Fullerton Hall. Subjects: "Non-Partisan Election of Aldermen, 50 Ward Plan;" "$29,000,000. Bond Issue;" "Relation of the Professional Technical Man to Civic Progress." Speakers: Messrs. Douglas Sutherland, Secretary, Civic Federation; Senator J. J. Barbour; Henry K. Holsman. This was a joint meeting with the General Committee Technical Societies of Chicago. Attendance 250.

October 29, 1919, Fullerton Hall. Subject: "Power Supply and Generation of the Future." Speaker: Dr. C. P. Steinmetz. Attendance 525.

November 24, 1919, Western Society Rooms. Subjects: "Personal Efficiency of the Employee;" "Electrical Power as a Factor in Effecting Economics and Increasing Production;" "Reaction of Labor to Intensive Lighting." Speakers: Messrs Harold Almert, Consulting Engineer; Geo. H. Jones, Power Engineer, Commonwealth Edison Co.; Edwin D. Tillson, Testing Engineer, Commonwealth Edison Co. Attendance 250.

Cleveland.—November 18, 1919, place of meeting Cleveland Engineering Society. Subject: "The Use of Electricity on the Farm." Speaker: Mr. C. W. Emerson, Consulting Engineer, Kewanee Private Utilities Co. The Section was honored by the presence of Mr. P. M. Lincoln, Past-President of the Institute.

Denver.—November 22, 1919, dinner at the Shirley Hotel. After dinner Chairman Evans called the meeting to order and reference was made to the Jones-Reavis Bill S-2232. Resolutions were adopted supporting this Bill. Speaker of the evening was Mr. A. L. Powell, who gave a very interesting lecture on the "Late Developments in Industrial Store and Residence Lighting" which was illustrated by lantern slides. Attendance 36.

Detroit-Ann Arbor.—November 14, 1919, Board of Commerce. Subject: "Synchronous Motor Characteristics." Speaker: Prof. B. F. Bailey of the University of Michigan.

Fort Wayne.—November 20, 1919, G. E. Co. Bldg. 16-2 Mr. J. J. Kline extracted a paper which had been delivered before the British Academy for the Advancement of Science by Mr. Charles A. Parsons, indicating engineering developments which had taken place during and as a result of the war. Attendance 45.

Indianapolis-Lafayette.—November 14, 1919, Chamber of Commerce. Speaker: Mr. B. C. Groh, of New York. Subject: "Modern Problems of the Automatic Telephone Exchange." Attendance 86.

Ithaca.—October 24, 1919, Franklin Hall, Cornell University. Subject: "The Coming Science of Acoustical Engineering." Speaker: Professor V. Karapetoff, of Cornell University. Attendance 115.

Lynn.—November 19, 1919. G. E. Hall. Social meeting. A program of different forms of entertainment was provided and refreshments were served. Attendance 200.

December 3, 1919, G. E. Hall. Subject: "The Development of the Incandescent Lamp and its Manufacture." Speaker: Mr. J. W. Howell, Chief Engineer, Edison Lamp Factories, Harrison, N. J. Attendance 150.

Madison.—November 7, 1919, Engineering Building. Chairman was authorized to appoint a committee to investigate the present status of Water Power Legislation and make a report at next meeting. The report of the Development Committee of the Institute was discussed by Prof. Watson. Attendance 9.

Minnesota.—November 10, 1919, Dunwoody Institute. Dr. C. A. Prosser and Mr. K. W. Kavel outlined the operation of the Dunwoody Institute of Minneapolis, in which 17,000 young men and boys have received training for a trade. An inspection of the building and equipment with the evening classes in session was made. Attendance 50.

Panama.—November 3, 1919, Coco Solo Submarine Base. Meeting consisted of an inspection trip to the U. S. Naval Submarine Base at Coco Solo, Canal Zone, and talks given by Lieut. R. L. Vaughn, Engineer Officer, and Mr. W. L. Hersh, Electrical Engineer of the Panama Canal, who designed the Submarine Storage Battery Charging Station. Attendance 40.

Philadelphia.—December 8, 1919, Engineers Club. Paper: "Automobile Headlight Legislation." Speaker: Mr. Clayton H. Sharp. Discussion was entered into by Messrs. Harold Pender, C. E. Clewell, representatives of Automobile Club, and by Benj. Eynon, Registrar of Motor Vehicles for the State of Pennsylvania. Attendance 100.

Pittsburgh.—November 11, 1919, Chamber of Commerce Auditorium. Paper: "The Design and Application of Electric Propulsion Equipment for Submarines." Speakers: Messrs. D. Hall and L. G. Riley, Engineers, Westinghouse Elec. & Mfg. Co. Attendance 55.

December 9, 1919 Chamber of Commerce Auditorium. Paper: "The Power Indicating and Limiting Apparatus for the Columbia and Coast Divisions of the C. M. & St. P. Railroad Company" by Mr. H. B. Smith, Engineer, Westinghouse Elec. & Mfg. Co. Attendance 80.

Portland.—November 18, 1919, University Club. Paper: "Some War Time Developments in Electrical Communication and Allied Fields" by Dr. F. B. Jewett. Dr. Jewett's talk was illustrated with stereopticon slides and moving pictures. Attendance 125.

Rochester.—December 5, 1919. Address by Mr. Will Brown, of the Electrical Machinery Co., on "How Load Driving Synchronous Motors are Helping the Power Factor Situation." Attendance 37.

San Francisco.—November 24, 1919, Native Sons' Hall. Paper: "Some Wartime Developments in Electrical Communication and Allied Fields" by Dr. F. B. Jewett. Attendance 270.

St. Louis.—November 19, 1919, Engineers Club. Joint meeting with the Associated Engineering Societies of St. Louis. Mr. Otto B. Blackwell, Transmission and Protection Engineer, American Telephone & Telegraph Co., gave an illustrated talk on the Telephone Transmission Circuit. Attendance 108.

December 3, 1919, American Annex Hotel. Election of officers for 1920 as follows: G. A. Waters Chairman, and Stanley Stokes, Secretary-Treasurer. Col. E. J. Spencer Secretary-Treasurer of the St. Louis Electrical Board of Trade gave in a most interesting way his reminiscences of experiences during the early days of electrical development. Short talks of this same nature were given by Messrs. H. H. Humphrey E. J. Pietzcker and H. I. Finch. Attendance 52.

Schenectady.—November 21, 1919, Edison Club Hall. Illustrated lecture by Mr. E. F. W. Alexanderson, Radio Engineer, General Electric Company on "Trans-Oceanic Radio Communication." Attendance 325.

December 5, 1919, Edison Club Hall. Illustrated lecture by Mr. W. L. R. Emmet, Consulting Engineer, General Electric Company on "Electric Ship Propulsion." Mr. Emmet gave a history of the electric drive for ships from the time of its inception to the present. He described in detail the present electric drive as installed in the "New Mexico" "California," etc. Attendance 355.

Seattle.—October 21, 1919, Chamber of Commerce. Mr. Sweat read an interesting paper illustrated by photographs and blue prints, describing the application of electric motor drive to auxiliary equipment on board ships. Attendance 45.

Spokane.—November 14, 1919, Davenport Hotel. Dinner in honor of Dr. F. B. Jewett. Matters affecting local sections were discussed informally. Attendance 15.

November 14, 1919, Davenport Hotel. Meeting of the Associated Engineers of Spokane under the auspices of the local Section of the A. I. E. E. Lecture by Dr. F. B. Jewett on "Some Wartime Developments in Electrical Communication and Allied Fields" illustrated with slides and moving pictures. Attendance 165.

Toronto.—November 21, 1919, Engineers Club. Paper on Electric Welding by Mr. F. K. D'Alton. The different methods of welding in use were enumerated, followed by a short description of the well known chemical elements contained in the various forms of iron and steel which must be taken into account in welding. After touching on gas welding the speaker went very thoroughly into electrical welding, covering both spot and fusion welding. A considerable number of slides were shown. Attendance 66.

Utah.—November 9, 1919, Commercial Club. Paper: "Some Wartime Developments in Electrical Communication and Allied Fields" by Dr. F. B. Jewett. Attendance 109.

November 29, 1919. Commercial Club. Subject: "Modern Illuminating Engineering." Speaker: A. L. Powell. Attendance 30.

PAST BRANCH MEETINGS

University of Arkansas.—November 18, 1919, Engineering Hall. Papers: "The Use of Storage Batteries in Automobile Work" by E. P. O'Neal; "Homer-Roberts Selective and Lock-out Telephone System" by Fred Moore. Attendance 16.

November 25, 1919. Talk by Professor Stetzner on "The Engineer as An Economist"; "European Engineers vs. American Engineers" by Guy Ixby; "The History of the Incandescent Lamp" by Max Ware. Attendance 26.

December 2, 1919, Engineering Hall. Papers: "Electric Motors vs. Gasolene Motors in Street Railway Work" by Wm. Nelson; "Electricity Direct from Fuel" by S. Felsenthal. Attendance 15.

Armour Institute of Technology.—October 7, 1919. Talk by Prof. E. H. Freeman on Benefits and Advantages of being affiliated with the A. I. E. E. Attendance 50.

November 5, 1919. Talks by Prof. E. H. Freeman on "Qualities of the Successful Engineer;" E. C. Lang on "What is Expected of the Coll ge Graduate;" R. Fischell on "Choosing a Vocation after Graduation." Attendance 35.

Brooklyn Polytechnic Institute.—November 21, 1919, Potts Lecture Room. Talk by Mr. Martin C. Hughes, New York Edison Co., on "Report Writing." Refreshments were served. Attendance 35.

University of California.—November 5, 1919. Papers: "Three-Phase Locomotive" by C. W. Robbins, and "Kern River Hydroelectric Plant" by L. F. Boerner. Attendance 30.

Carnegie Institute of Technology.—November 25, 1919, Machinery Hall. Paper: "Mechanical and Electrical Features of the West Penn Power Co's Plant at Springdale, Pa." by Messrs. G. G. Bell, Geo. S. Humphrey and H. W. McRobbie, all of the West Penn Co. Illustrated with lantern slides, photostat cuts and blue prints of plans and work at the new plant. Attendance 48.

University of Cincinnati.—November 4, 1919. Paper by Prof. A. M. Wilson on "The Value of Education and What the World Expects from the Educated Man." Attendance 96.

November 18, 1919, Assembly Room, Engg. Bldg. Talk by Mr. Chas. Britten, of the Hyatt Roller Bearing Co., on Roller Bearings for Electrical and Other Machines. Attendance 67.

November 25, 1919, Engineering Bldg. Talk by Mr. J. A. Brett, General Manager of the Cincinnati office of the Westinghouse Elec. & Mfg. Co., on "What Westinghouse is Doing and What are the Chances for Engineers in their Work." Attendance 79.

Clemson Agricultural College.—October 21, 1919, Electrical Engineering Lecture Room. Paper: "Outdoor Illumination" by Mr. A. F. Holley. Other subjects: Current Events, by M. J. Black, and Life of Edison by R. B. Bratton. Attendance 58.

November 4, 1919, Elec. Engg. Lecture Room. Paper: "Storage Batteries" by H. D. Cordes. Other subjects: Current Events by J. O. Brown and Life of Lord Kelvin by J. R. Clark. Attendance 53.

November 18, 1919, Elec. Engg. Lecture Room. Paper: "Farm Lighting Plants" by J. B. Fitzgerald. Other subjects: Current Events by J. D. Salbey, and Life of Elihu Thompson by W. H. Abernathy. Attendance 67.

December 2, 1919, Elec. Engg. Lecture Room. Paper: "High-Tension Transmission" by C. C. Graves. Other subjects: Current Events by B. C. Cobb and Incandescent Lamp by N. G. Rentz. Attendance 59.

University of Colorado.—December 5, 1919. Talk by Mr. Fred W. Hild, General Manager of the Denver Tramway, on the electric tramway problems. Attendance 69.

Kansas State Agricultural College.—November 6, 1919. Paper: "Residence Lighting" read by D. S. McHugh. Illustrated with slides furnished by National Lamp Works. Attendance 73.

November 13, 1919. An explanation and demonstration of the oscillograph by Prof. C. E. Reid. Attendance 72.

University of Kentucky.—December 4, 1919, Mechanical Hall. Three ten-minute talks—"Military Searchlights and Their Scientific Testing" by J. H. Bailey; "Factory Lighting, A Central Station Problem" by H. P. Boone; "Hydroelectric Plant and Paper Mill at Ocean Falls, B. C." by J. Bromagen. Attendance 20.

Lehigh University.—December 4, 1919, Physics Bldg. Papers: "Wireless Telephone" by J. A. Cadwallader; "Wireless Telephone Experiments" by Prof. S. S. Seyfert. Attendance 98.

University of Maine.—November 8, 1919, Lord Hall. Illustrated lecture on arc welding by Messrs. Libby and Holslag, both of the Electric Arc Welding Co., N. J. Attendance 62.

Massachusetts Institute of Technology.—December 5, 1919. Paper: "Economic Development of Electrical Industry" by B. A. Behrend. Attendance 50.

University of Michigan.—November 6, 1919, Engineering Bldg. Business meeting. Attendance 19.

Michigan Agricultural College.—November 25, 1919. Paper: "The World's Mightiest Electric Locomotive" presented by Prof. M. M. Cory. Illustrated by films "The King of the Rails." Attendance 98.

School of Engineering of Milwaukee.—November 21, 1919. Illustrated talk on Hydroelectric Developments in America by Mr. W. M. White, Chief Engineer of the Allis-Chalmers Co. and President of the Engineers Society of Milwaukee. Attendance 241.

University of Missouri.—November 17, 1919, Engineering Bldg. Paper: "Protective Devices" by T. V. LeBow. Attendance 15.

University of Nebraska.—November 12, 1919, Mech. Eng. Bldg. Subject: "Business Relations of the Engineers." Speakers: Messrs. D. E. Byerley and O. J. Fee. Attendance 42.

University of North Carolina.—November 17, 1919. Papers: "Telegraphie Por le Sol" by C. P. Bolick; "The Use of Radio in Our Anti-Submarine Campaign" by W. F. Alston. Attendance 52.

North Carolina State College.—November 13, 1919, E. E. Class Room. Papers. "The Gas Electric Automobile" by F.

A. Long; "Points about Installation of Motors" by C. E. Rhodes; "A New Wireless" by R. S. Collins. Attendance 21.

November 20, 1919, E. E. Class Room. Papers: "Electricity Applied to the Modern Restaurant" by F. P. Huskin; "Electric Locomotives" by M. L. Matthews. Attendance 18.

December 4, 1919, E. E. Class Room. Talk by Mr. W. M. Gallant on the history of the Westinghouse Co. and the apprenticeship course at East Pittsburgh. Attendance 26.

Ohio Northern University.—November 12, 1919, Dukes Memorial. Papers "The Erie Plant of the General Electric Co." by Mr. A. B. Tourtellot; "Isolated Electric Lighting Plants" by Mr. L. D. Beatty. Attendance 21.

December 10, 1919. Lehr Memorial. The following films were shown: "Railroad Electrification"; "King of the Rails;" "The Potter's Wheel." Attendance 250.

Ohio State University.—November 17, 1919, Robinson Laboratory. Business meeting. Attendance 42.

December 5, 1919, Physics Hall. Paper: "Development and Meaning of Illuminating Engineering" by Mr. S. E. Doane. Attendance 173.

Oregon Agricultural College.—October 21, 1919. Business meeting at which Prof. Dearborn explained the purpose and aims of the Student Branch of the A. I. E. E. Attendance 31.

November 19, 1919. Mr. Fred A. Roehrig elected President. Illustrated talk by Mr. F. N. Waters on "Recent Submarine Development." Attendance 55.

Purdue University.—October 28, 1919, Electrical Building. Talks: "Signal Corps Experiences Overseas" by W. H. Snyder; "The Purdue Radio Station" by N. C. Pearcy. Demonstration of wireless apparatus by R. A. Deller and W. D. Freezer. Attendance 95.

November 18, 1919, Electrical Building. Papers: "Electricity and its Progress" by W. B. Nottingham; "Commercial Watthour Meter Testing" by T. K. Hartley; "Railway Electrifications" by Prof. D. D. Ewing. Attendance 150.

November 24, 1919, Electrical Building. Paper: "Manufacture of High-Tension Insulators" by W. A. Hildebrand, Ohio Brass Co., Mansfield, O. Attendance 80.

Stanford University.—November 25, 1919, Electrical Engg. Bldg. Business meeting. Attendance 9.

Stanford University.—December 8, 1919, Elec. Engg. Bldg. Following officers elected—Chairman Aubrey Smith, Vice-Chairman Raymond Lewelling. Professor Harris J. Ryan addressed the meeting on the history of the A. I. E. E., and of the profession in general in America, giving facts about the organization and progress of the Institute. Attendance 15.

A. & M. College of Texas.—November 10, 1919, E. E. Bldg. Talk by W. M. Denny on "Methods of Protection of Employees." Attendance 78.

December 1, 1919, E. E. Building. Talks: "Arc. Welding" by Sgt. Harding; "Power Plant Operation" by Lieut. Burnheim. Attendance 59.

University of Texas.—November 19, 1919. Organization meeting. Following officers were elected—Chairman W. J. Miller, Secretary and Treasurer Clyde Young. Attendance 27.

University of Virginia.—December 4, 1919, Rouse Physical Laboratory. Paper: "Pyrometers" by Dr. L. G. Hoxton. Attendance 25.

Virginia Polytechnic Institute.—November 24, 1919. Lecture by L. D. Fry on the "Mercuric Arc Rectifier." Attendance 29.

November 10, 1919. Messrs. Ray Smith and A. W. Fairer performed an experiment before the members, illustrating how to change a single-phase current to a three-phase current for use on electric railways. Attendance 28.

December 8, 1919. Lectures by Messrs. R. W. Gaskins and W. R. Dixon on the construction and maintenance of the lead plate storage cell and the Edison alkaline storage cell. Attendance 17.

West Virginia University.—November 10, 1919, Mechanical Hall, Election of officers as follows: President H. J. Walls, Vice-President P. H. Sommer, Secretary M. Wilcoxen, Treasurer L. E. Stone. Attendance 16.

November 14, 1919, Engg. Assembly Room. Papers: "Two Hundred and Twenty Kilovolt Transmission Line" by J. M. Frum; "Alternating-Current Clocks" by H. J. Walls; "Electric Welding" by R. J. Stoker; "Induction Motors" by P. D. McDonald; "Pole and Tower Lines" by J. E. Jolliffe; "Development of Substations" by B. Noyes; "Electric Mine Hoist" by C. R. Bickel; "Review of A.-C. Machine Design" by W. C. Fisher; "Phase Splitters" by P. H. Sommer; "Review of Electrical Review" by R. D. Sheffer; "Review of Electrical Journal" by L. E. Stone. Attendance 35.

Washington University.—November 18, 1919. Chairman Bowles and Dean Langsdorf spoke on the purpose of the Branch and the organization of the national body. Mr. Waters of Wagner Electric Co., St. Louis, gave a very interesting and forceful talk on "The Electrical Engineer in the Manufacturing Industry." Refreshments served. Attendance 43.

University of Washington.—November 4, 1919, Forestry Hall. Paper: "Multiplex Radio Telegraphy and Telephony" by Messrs. E. M. Ryan, R. O. Bach and J. R. Tolmie. Attendance 25.

State College of Washington.—October 10, 1919. Subject: "Modern Artillery Practise." Speaker: Major F. C. Tucker. Attendance 38.

November 21, 1919. Subject: "Advertising" Speaker: Prof. M. K. Snyder. Attendance 30.

Worcester Polytechnic Institute.—November 14, 1919, E. E. Hall. Talks by Harry W. Tenney on "Experiences with the Joseph Campbell Co., Camden, N. J.," and Norman P. Marks on "Experiences in Electrical Drafting with the Scovill Mfg. Co., Waterbury, Conn." Attendance 31.

Yale University.—October 3, 1919. Informal talks by Prof. Chas. F. Scott, Prof. Harold V. Bozell, Prof. Lester W. Morrow, Prof. H. M. Turner, Lieut. Col. Hineman, Signal Corps, U. S. A., and Mr. D. F. Hine. Attendance 54.

October 17, 1919. Subject: "War Work and Engineering Developments, General Electric Company" by Mr. F. C. Pratt. Attendance 170.

October 29, 1919. Subject: "Outline of General Field of Signal Corps Work in France During the War" by Lieut. Col. Sawyer, Signal Corps, U. S. A. Attendance 16.

MEMBERSHIP

Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED DECEMBER 12, 1919

ADSETT, FREDERICK C., Local Manager, Hydro-Electric Power Commission, Trenton, Ont., Canada.

*AIMUTIS, FRANK J., Designing Electrical Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

ALLEN, L. E., Dist. Manager, Commonwealth Public Service Co., Ozark, Ark.

ARNOLD, HENRY B., Technical Service Dept., Western Electric Co.; res., Y. M. C. A., 23rd St., New York, N. Y.

ASHWORTH, PAUL P., Distribution Engineer, Utah Power & Light Co., Kearns Bldg., Salt Lake City, Utah.

AUBREY, CHARLES A., Electrician, United Illuminating Co.; res., 102 Harral Ave., Bridgeport, Conn.

BARKER, SPRAGUE, Chief Draftsman, Frank Adam Electric Co., St. Louis, Mo.

BARTON, ROY A., Chief Engineer, Portland Flouring Mills Co.; res., 1203 Wilbur St., Portland, Ore.

BOWEN, WILLIAM EARL, Radio Electrician, In Charge of Laboratory, Norfolk Navy Yard, Portsmouth, Va.

BRENNAN, AUSTIN H., Plant Electrician, Submarine Boat Corp.; res., 86 Bleeker St., Newark, N. J.

BROOKE, GEORGE M., Electrician, Rio Grande Public Service Corp., McAllen, Texas.
*BURT, F. R., General Engineering Div., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
CAMPBELL, J. Archibald, 226 West 238th St., New York, N. Y.
CARNEY, JOHN J., Engineering Dept., Bristol Co.; res., 236 Hillside Ave., Waterbury, Conn.
CARPENTER, HENRY H., Electrical Engineer, Blackstone Valley Gas & Electric Co.; res., 48 Maple St., Woonsocket, R. I.
CATHEY, BEN L., Chief Electrician, Detroit Seamless Steel Tubes Co.; res., 190 Allendale Ave., Detroit, Mich.
CLARKSON, WILLIAM B., Engineer, General Electric Co.; res., 109 Woodland Ave., Schenectady, N. Y.
CORBIN, ALFRED G., Foreman & Elec. Inspector, Welding Basin, American International Shipbuilding Corp., Hog Island, Pa.
COX, I. EUGENE, Electrician, National Enameling & Stamping Co. Steel Works Branch, Granite City, Ill.
CRAWFORD, WILLIAM J., Student Engineer, Cutler-Hammer Mfg. Co., 175 16th St., Milwaukee, Wis.
CRIM, LE ROY C., Chief Engineer, Southern N. Y. Power & Railways Corp., Hartwick, N. Y.
DAHLSTROM, FRANK P., Electrician, American Steel & Wire Co.; res., 179 W. Boylston St., Worcester, Mass.
DANVERS, W. K., Electrical Engineer, Oklahoma Railway Co., 213 Terminal Bldg., Oklahoma City, Okla.
DEELWATER, CARL L., Electrical Tester, Diehl Mfg. Co., Elizabeth, N. J.
*DOYLE, HUGH P., Electrical Engineer, International General Electric Co., 23 Water St., Yokohama, Japan.
DURAISWAMY, C. S., Engineer, Doom Dooma Tea Co., Ltd., Hansara Div., Doom Dooma, Assam, India.
ECHEVARRIA, ARTHUR B., Office Head & Electrical Engineer, "Central Vannina", Rio Piedras, Porto Rico.
EDKINS, EARL V., Electrician, Atlantic Refining Co.; res., 5827 Trinity Place, W. Philadelphia, Pa.
FAIREY, ARTHUR R., Chief Inspecting Engineer, Insulating & Winding Depts., The British Westinghouse Co., Trafford Park, Manchester, Eng.
FARRELL, CHRISTOPHER C., Asst. Electrical Engineering, American Railways Co.; res., 3808 Spring Garden St., Philadelphia, Pa.
FREEMAN, WILLIAM G., Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
GARDNER, HARTLEY B., Instructor of Electrical Engineering, Mass. Institute of Technology, Cambridge, Mass.
GARDNER, LELAND A., Engineering Dept., Bijur Motor Appliance Co., Hoboken, N. J.
GATLAND, H. CHARLES, Elec. Engineer, Wairua Power Station, Titoka P. O., Whangarei, Auckland, N. Z.
GELLION, FREDERICK JOHNSON, Engineer & Manager, Electric Lighting Co. Ltd., Macao, So. China.
GINOCCHIO, JAMES A., Electrical Draughtsman, Charles E. Knox Associates, 101 Park Ave., New York, N. Y.
GLEASON, JOHN C., Operating Power Plant Engineer, Germain & Boyd Lumber Co., Atlanta, La.
GOODRICH, CHAUNCEY M., Designing Engineer, The Canadian Bridge Co., Ltd., Walkerville, Ont.
GRACE, IAN WALTER, Elec. Engineer, Martinborough Town Board, Martinborough, Wairarapa, N. Z.
*GRAM, JOHN IRWIN, Asst. Meter Engineer, Ontario Power Co.; res., 43 Main St., Niagara Falls, Ontario.
HARRIS, FRED R., Chief Engineer, Michigan Public Utilities Commission, Lansing, Mich.
HARTVIG, C. E., Signal Supervisor, C. R. I. & P., R. R., 31st. Station, Rock Island, Ill.
HELFRICH, F. A., Electrical Supervisor, Baltimore & Ohio Railroad; res., 1206 Longwood St., Baltimore, Md.
HEYMAN, MORRIS, 1887 Madison Ave., New York, N. Y.
HOFFMAN, ALFRED G., Testing Dept., General Electric Co.; res., 710 South Ave., Schenectady, N. Y.
HUNT, CHARLES M., Sales Engineer, Roller-Smith Co., 233 Broadway, New York, N. Y.
HUNTER, HOWARD V., Engineer, Dept. of Development & Research, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
HUTCHINGS, JOHN MARVIN, Student Engineer, The Emerson Electric Mfg. Co., 2032 Washington Ave., St. Louis, Mo.
*IDAIL, MURRAY J., Electrical Engineer, with F. R. Weller, 408 Hibbs Bldg., Washington, D. C.
JONES, J. W., 1st Shift Engineer, Wairua Falls Power House, Titoki, Whangarei, Auckland, N. Z.
KAWAMATA, TAKASHI, Student, Cornell University, res.; 112 Ferris Place, Ithaca, N. Y.
KELLY, JAMES F., Plant Engineer, Public Service Electric Co., 80 Park Place, Newark, N. J.
KELLY, PATRICK, Commercial Engineer, International General Electric Co., Schenectady, N. Y.
KENT, PIERCE J., Chief System Operator, Edison Electric Illuminating Co., S. Boston; res., 17 Morrill St., Dorchester, Mass.
LAGRANGE, DANIEL E. H., Directeur, de la Firme, La Soudure Electrique Autogene, rue de la Pepiniere, N°18, Bruxelles, Belgium.
*LAWRENCE, MERRITT T., Testing Dept., General Electric Co.; res., 205 Seward Place, Schenectady, N. Y.
MAC DOUGALL, CHARLES G., Sales Engineer, Canadian General Electric Co., King & Simcoe Sts., Toronto, Ont.
MAC FADDEN, Samuel P., Asst. to Railway Supt., Eastern Texas Electric Co., Beaumont, Texas.
MAHLMEISTER, EUGENE J., Jr., Inspector, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.
MARGETTS, WILLIAM LESTER, Asst. Electrical Engineer, Havana Central R. R. Co., Havana, Cuba.
*MARICH, WILLIAM D., Foreman, Elec. Testing Dept., American International Shipbuilding Corp., Hog Island, Pa.
MASUMI, KEIZO, Engineer, Yasukawa Electric Works, Kurosakimachi, Fukuokaken, Japan.
MATTHEWS, CAREY T., Manager, Town of Lillington, Lillington, N. C.
MAYNARD, ALEXANDER R., Sales Manager, Western Electric Co., Inc., Detroit, Mich.
McCONNAUGHEY, EUGENE C., Division Equipment Inspector, Western Union Tel. Co., 800 Transportation Bldg., Atlanta, Ga.
*McELROY, DAVID W., Engineer, Railway & Lighting Dept., General Electric Co., of Cuba, Havana, Cuba.
*MILLER, MERRITT B., Student, Purdue University, 500 N. Salisbury St., W. Lafayette, Ind.
*MILLER, W. J., Adjunct Prof. of Elec. Engineering, Univ. of Texas; res., 2620 Wichita St., Austin, Texas.
MOYER, H. WAYNE, Electrical Tester, Philadelphia Electric Co.; res., 4539 N. 17th St., Philadelphia, Pa.
MURRAY, LOUIS E., 1st Operator, Mt. Whitney Substation, So. California Edison Co., Porterville, Cal.
NEWBURY, ROBERT C., Engineer, Denver Gas & Elec. Light Co., Denver, Colo.
*NEWLANDER, RALPH A., Division Traffic Inspector, Western Union Tel. Co., 111 W. Jackson Blvd., Chicago, Ill.
NEWMARK, MORRIS, Supt. & Estimator, for David Dunn, 1136 Girard Ave., Philadelphia, Pa.
OIKAWA, HOTORI, Prof. of Elec. Engineering, Port Arthur Technical Institute, Port Arthur, Japan.
PAPAMARCO, DEMETRI, Stationary Engineer; res., 356 Clifton Place, Brooklyn, N. Y.
PARDEY, GILBERT R., Service Dept., Westinghouse Electric & Mfg. Co.; res., 39 St. Botolph St., Boston, Mass.
PATTERSON, JAMES F., Telephone Engineer, Northern Electric Co.; res., 7 Essex Ave., Montreal, Que.
PITTENGER, PAUL N., Resident Supervising Engineer, Lockwood, Greene & Co., Healy Bldg., Atlanta, Gal
RACAZA, VICENTE A., Electrical Engineer, Ormoc Electric Light Co., Ormoc, Leyte; res., 92 Juan Luna St., Cebu, Cebu, Philippine Islands.
*RIES, CASPER F., Tester, The Detroit Edison Co.; res., 510 Pasadena Ave., Detroit, Mich.
*ROYDEN, GEORGE T., Radio Laboratorian, Mare Island Navy Yard, 311 Ellsworth Ave., San Mateo, Cal.
RYAN, JOHN THOMAS, Industrial Engineer, Century Electric Co., 818 Bessmer Bldg., Pittsburgh, Pa.
SAYRE, EDGAR W., Draftsman, Wagner Electric Mfg. Co., 2018 Locust St., St. Louis Mo.
SCHACHT, ELMER C., 312 Decatur St., Sandusky, Ohio.
SCHILDKNICHT, ALBERT E., Asst. Instructor, Bliss Electrical School, Takoma Park, D. C.
SCHMIDT, JOHN FREDERICK, Foreman, Plant Maintenance, Federal Shipbuilding Co., Kearny, N. J.
SCHOENBERGER, JULIUS E., Electrical Draftsman, Charles E. Knox Associates, 101 Park Ave., New York, N. Y.
SCHWENDLER, RICHARD H., Aeronautical Engineer, 53 East 54th St., New York, N. Y.
SCOTT, WALTER, 2nd Engineer, Philadelphia Electric Co., Philadelphia; res., Lodges Lane, Cynwyd, Pa.
SEEM, FRED B., Supt. Telephone & Telegraph Empire Companies, Masonic Bldg., Bartlesville, Okla.
SEKIZAWA, SANKICHI, Engineer, Yasukawa Electric Works, Kurosakimachi, Fukuokaken, Japan.
SHAHAN, J. HUBERT, Test Dept., Diehl Mfg. Co.; res., 217 Inslee Place, Elizabeth, N. J.
SHAW, ALEXANDER HUNTLY, Operator, Surf Inlet Power Co., Surf Inlet, B. C.
*SLOAN, DAVID McCURTIE, Statistician, Carolina Power & Light Co., Raleigh, N. C.
SPLITSTONE, EDWARD L., Commercial Engineer, The Emerson Electric Mfg. Co., St. Louis; res., 114 Bompart Ave., Webster Groves, Mo.
STAEHLE, DANIEL, JR., Instructor, Electrical Dept., David Rankin Jr., School of Mech. Trades, St. Louis, Mo.
*STELLE, JOSEPH G., Asst. Switchboard Operator, New York Edison Co., New York; res., 53 Parcell St., Elmhurst, N. Y.

STEVENS, ROGER B., Supervisor, Div. of Plant Appraisal, American Sugar Refining Co.; res., 1933 S. Gayoso St., New Orleans, La.
STEWART, ROBERT J., Chief Operating Engineer, Edgewood Arsenal, Edgewood, Md.
STUDER, WALTER, Foreman, Electrical Dept., Ford Instrument Corp., New York; res., 655 Fresh Pond Road, Brooklyn, N.Y.
TAYLOR, HAWLEY O., Associate Physicist, Bureau of Standards; res., 122 E. Capitol St., Washington, D. C.
TODD, THOMAS, Purchasing Dept., Eastern Mass. Street Railway Co., Boston; res., 586 Walnut St., W. Lynn, Mass.
VODGES, FRANCIS B., Testing Dept., General Electric Co.; res., 205 Seward Place, Schenectady, N. Y.
WAY, WILLIAM RUSSELL, Asst. Engineer, Operating Dept., Shawinigan Water & Power Co., Power Bldg., Montreal, Canada.
*WHITE, B. LEE, Meterman, Monongahela Valley Traction Co., Fairmount, W. Va.
WHITE, JAMES M., Laboratory Asst., Northern Electric Co. Ltd., 121 Shearer St., Montreal, Quebec.
WHITEFIELD, WILLIAM I., Asst. Supt., L. & P. Dept., Roanoke Railway & Elec. Co., Roanoke, Va.
WILLIAMS, EDWIN T., Electrical Inspector, N. Y. C. R. R. Co., Grand Central Terminal, New York, N. Y.
WILLSON, ABNER R., Apex, Bingham Canyon, Utah.
WILSTAM, ALFRED, Electrical Engineer, So. California Edison Co., Edison Bldg., 3rd & Broadway, Los Angeles, Cal.
*WRIGHT, RALPH H., General Engineering Div., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Total 111
*Former enrolled student.

ASSOCIATE RE-ELECTED DECEMBER 12, 1919

BURCHER, REGINALD H., Outside Plant Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

MEMBERS ELECTED DECEMBER 12, 1919

BUCKLEY, OLIVER E., Research Engineer, Western Electric Co. Inc., 463 West St., New York, N. Y.
CABLE, MATTHEW, Acting Gen. Manager & Engineer, Tramway Department, Harris St., Wellington, N. Z.
CHARLTON, ALEXANDER MARK, Lieut-Comdr., U. S. N., Bureau of Steam Engg., Navy Dept., Washington, D. C.
HALL, EVERETT D., Division Head, Engineering Dept., Western Electric Co., 463 West St., New York, N. Y.
KELLER, LEO, Systems Engineer, Western Electric Co., 463 West St., New York, N. Y.
NIMMO, HENRY, Dist. Education Officer in Army, 52 The Common, Woolwich, London, S. E., 18, Eng.
PARKER, FREDERICK THOMAS, Major, Chief Elec. & Mech. Engr., Special Constr. Directorate, Civil Engineer-in-Chief's Dept., Admiralty, London, S. W., England.

Transferred to Grade of Member December 12, 1919

BROWN, CARROL G., Professor of Electrical Engineering, School of Engineering, Milwaukee, Wis.
FERGUSON, HOWARD F., District Engineer, Republic Engineers, Inc., Youngstown, O.
SCRIVENER, ROBERT M., District Manager, Alfred Collyer & Co., Toronto, Ont.
WEISS, FERNAND C., Superintendent of Construction, Alabama Power Co., Birmingham, Ala.
WHITING, DONALD F., Electrical Engineer, Special Research Division, Western Electric Co., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting, held on December 8, 1919, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

TO GRADE OF FELLOW

BALL, JOHN D., Vice-President and Dean, School of Engineering of Milwaukee, Milwaukee, Wis.
GREEN, CHARLES M., Research Laboratory, General Electric Co., Lynn, Mass.

TO GRADE OF MEMBER

BURCHER, REGINALD H., Outside Plant Engineer, American Tel. & Tel. Co., New York, N. Y.
DANE, LOUIS P., Asst. Chief Engineer, Railway & Industrial Engineering Co., Greensburg, Pa.
DAVIDSON, WARD F., Instructor in Electrical Engineering, University of Michigan, Ann Arbor, Mich.
HARDY, NORMAN G., Chief Mechanical and Electrical Engineer, The Arizona Copper Co. Ltd., Clifton, Ariz.
HOGAN, JOHN V. L., Manager, International Radio Telegraph Co., New York, N. Y.
LENNARD, WILLIAM H., Electrical Supt., The Haughton Elevator & Machine Co., Toledo, O.
OAKES, CHARLES E., Associate Electrical Engineer, Bureau of Standards, Washington, D. C.
PIERCE, GUY C., Vice-President and General Manager, Northwestern Electric Co., Portland, Ore.
SIMPSON, FRANK, Manager St. Louis District, Pittsburgh Transformer Co., St. Louis, Mo.
WEIGHTMAN, HUGH E., Director, Research Division, Atlas Electric Devices Co., Chicago, Ill.
WURTS, THOMAS C., Heavy Traction Section, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1920.

Abbott, Donald A., Ft. Wayne, Indiana.
Anderson, William F., Toledo, Ohio.
Anderton, Thomas R., Dover, New Hampshire.
Appuhn, William E. F., Brooklyn, N. Y.
Arnold, Ellis J., Ann Arbor, Michigan.
Aslanides, D. J., E. Pittsburgh, Pennsylvania.
Bach, Roy O., Seattle, Washington.
Bacon, Marion F., Ft. Wayne, Indiana.
Baker, Douglas B., New York, New York.
Baker, George C., Brooklyn, N. Y.
Baker, Henry S., Niagara Falls, Ontario.
Ballard, Harold L., Ann Arbor, Michigan.
Ballew, Walter W., Atlanta, Georgia.
Beedenbender, Harry L., Yonkers, New York.
Benjamin, Abraham S., Chicago, Illinois.
Bennett, Rolland H., San Francisco, California.
Bewlay, Henry F., (Member), Mansfield, Ohio.
Bicak, Edward T., (Member), New York, N. Y.
Bolton, John I. N., Toronto, Ontario.
Boyere, Emery E., Green Bay, Wisconsin.
Brinkman, Erwin E., Milwaukee, Wisconsin.
Browning, Hardy P., Fort Sam Houston, Texas.
Brunson, Lawrence W., Ann Arbor, Michigan.
Burger, Edward J., San Bernardino, California.
Billstein, Arthur E. F., Philadelphia, Pennsylvania.
Birch, Leland W., Hartsville, South Carolina.
Blatchley, Henry, New Haven, Connecticut.
Blunk, Adolf, Durham, North Carolina.
Bond, Thomas D., Boston, Massachusetts.
Brackett, William H., Montreal, Quebec.
Brown, Henry S., Ottawa, Ontario.
Brunson, Lawrence W., Ann Arbor, Michigan.
Cappon, Marvin T., Montour Falls, New York.
Church, Leroy, Redbank, New Jersey
Colburn, Wellen H., Lynn, Massachusetts.
Cowgill, Lester B., Seattle, Washington.
Cox, Carl C., Fort Worth, Texas.
Dart, Harry F., Scranton, Pennsylvania.
Dominick, William G., Pittsfield, Massachusetts.
Eberhardt, Wallace W., Birmingham, Alabama.
Eslick, Everett, E. Pittsburgh, Pennsylvania.
Ellsworth, G. L., Colton, California.
Fairman, James F., Ann Arbor, Michigan.
Fonstermacher, Charles N., New York, N. Y.
Fowler, Clarence B., New York, New York.
Friis, H. Trap, New York, New York.
Fronmuller, Theodor C., San Francisco, California.
Gadberry, Joseph L., Dallas, Texas.
Galsteren, Andrew, San Francisco, California.
Gefke, Jerome H., Milwaukee, Wisconsin.
Gemmill, Melvin E., Sparrows Point, Maryland.
Gittings, William N., Schenectady, New York.
Glasser, Charles E., Schenectady, New York.
Goldhammer, Charles J., Elkhart Lake, Wisconsin.
Grafing, Fred H., Brooklyn, New York.
Halls, Robert A., Philadelphia, Pennsylvania.
Halporn, Arnold D., Philadelphia, Pennsylvania.
Harbert, William H., Hailey, Idaho.
Hasegawa, Keizo, New York, New York.
Havens, Charles B., Denver, Colorado.
Hempsey, Charles E., New York, New York.
Hefstetter, Carl F., St. Louis, Missouri.
Henderson, Charles W., Syracuse, N. Y.
Hoffman, Edward L., Chicago, Illinois.
Hotchkiss, Fred W., Minneapolis, Minnesota.
Hughes, Calvin T., Waterbury, Connecticut.
Hughes, Martin C., New York, New York.

Hulatt, H., Montreal, Quebec.
Hyatt, Sidney M., Milwaukee, Wisconsin.
Johnson, Lewis H., (Member), New York, N. Y.
Juhnke, Paul B., (Member), San Francisco, Cal.
Kaufman, George A., Munhall, Pennsylvania.
Keesling, Hector, San Francisco, California.
Klee, William A., (Member), St. Louis, Missouri.
Kleist, Walter A., Seattle, Washington.
Klumbach, Hampton R., Syracuse, New York.
Koonsman, Harold D., Detroit, Michigan.
Kurtz, Edwin B., Ames, Iowa.
Lankton, William W., Detroit, Michigan.
Lubeke, Charles M., Seattle, Washington.
Lundell, Carl H., (Member), Portland, Oregon.
MacAlister, Alexander G., Philadelphia, Pennsylvania.
Magee, James F., Allentown, Pennsylvania.
Maggi, Guy J., New York, New York.
Mathes, Robert C., New York, New York.
Merkel, Oswald H., Ludlow, Massachusetts.
Meyer, Charles C., Philadelphia, Pennsylvania.
Miller, Claude A., Tacoma, Washington.
Moore, Raymond P., Buffalo, New York.
Moser, Harry W., Hog Island, Pennsylvania.
Muellman, Joseph P., Chicago, Illinois.
McCartin, James W., Philadelphia, Pennsylvania.
McClure, Edward W., Preston, Idaho.
McDowell, Hamilton E., Allentown, Pennsylvania.
McElhose, Irving H., Utica, New York.
McKibbin, Robert H., Phoenix, Arizona.
Nairn, John M., Pittsburgh, Pennsylvania.
Nelson, E. C., Schenectady, New York.
Nethercut, Donald W., Mansfield, Ohio.
Norman, Earl E., Atlanta, Georgia.
Novak, Frank L., New York, New York.
Oehlschager, William A., Trenton, New Jersey.
Pelaez, Ernesto C., Cleveland, Ohio.
Poe, Charles R., New York, New York.
Pomeroy, William C., Berkeley, California.
Porges, Edward D., Indianapolis, Indiana.
Porter, H. L., Cleveland, Ohio.
Predock, Norvill H., St. Louis, Missouri.
Ross, Russell H., Minneapolis, Minnesota.
Rowand, Alfred M., Ada, Ohio.
Schlenk, Hugo, Jr., Minneapolis, Minnesota.
Schwartz, Emil E., New York, New York.
Sechrist, Gilbert H., Ruston, Louisiana.
Shaw, Harold N., Milwaukee, Wisconsin.
Smith, Winfred W., Palmerton, Pennsylvania.
Smithson, Earl W., New York, N. Y.
Smythies, Reginald E., Toronto, Ontario.
Spoon, Philip, Jackson, Michigan.
Sporn, Max E., New York, N. Y.
Stacy, John D., Pittsfield, Massachusetts.
Stanford, Leland H., Fort Sam Houston, Texas.
Stevens, John C., (Member), Portland, Oregon.
Storm, Hans O., Stanford University, California
Stuart, Virgil N., New York, New York.
Sudderth, D. Glenn, Jr., Atlanta, Georgia.
Sumner, William A., E. Pittsburgh, Pennsylvania.
Swisher, Arthur W., Hog Island, Pennsylvania.
Thomas, Milton A., Waterbury, Connecticut.
Tranick, Henry P., Schenectady, New York.
Utley, Romeyn L., Newark, New Jersey.
Walther, Harry L., (Member), Medford, Oregon.
Warner, Harry O., Washington, D. C.
Wehle, Paul G., New York, New York.
West, Harry R., Philadelphia, Pennsylvania.
Whiting, Arthur C., New York, New York.
Whittle, Horace, New York, New York.
Withers, Francis P., Chicago, Illinois.
Whipperman, Frederic B., St. Louis, Missouri.
Whitcomb, Arthur J., Chicago, Illinois.
Yost, Charles H., Erie, Pennsylvania.
Young, Levi F., Kansas City, Missouri.
Zeiger, Louis B., Brooklyn, New York.
Zippler, William N., Philadelphia, Pennsylvania.
Total 143.

Foreign

Day, Bernhard F. J., London, England.
Deane, Tsung Y., Shanghai, China.
Ekdahl, Edwin A., Shanghai, China
Ewing, Sydney E. T., (Member), Johannesburg, S. Africa.
Henderson, Horace W. W., (Member), London, Eng.
Houston, Robert, Leeton, N. S. Wales, Australia.
Leonida, Dimitrie, (Member), Bucharest, Roumania.
Reese, Clarence B., Rancagua, Chile, S. A.
Total 8.

STUDENTS ENROLLED

DECEMBER 12, 1919

10671 Ochoa, George V., University of Illinois
10672 Schmitt, Arthur E., University of Illinois
10673 Pinckard, Frank E., University of Cincinnati
10674 Kepler, Lionel J., University of Cincinnati
10675 Hannum, Dane M., University of Cincinnati
10676 Huss, Frank W., Jr., University of Cincinnati
10677 Meyer, Charles S., University of Cincinnati
10678 Kemper, W. F., School of Engineering of Milwaukee
10679 Reading, J. E., School of Engineering of Milwaukee
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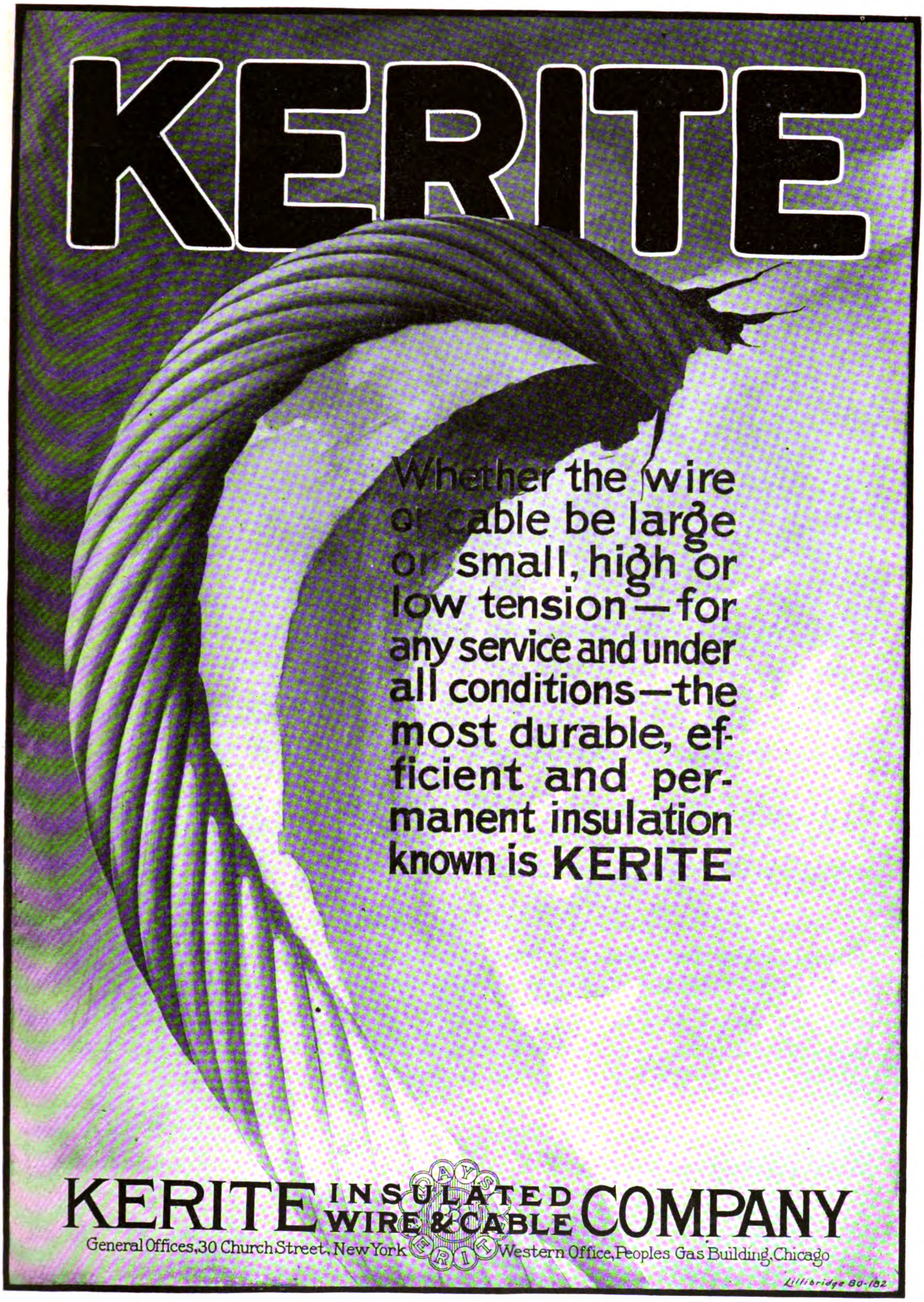
Total 62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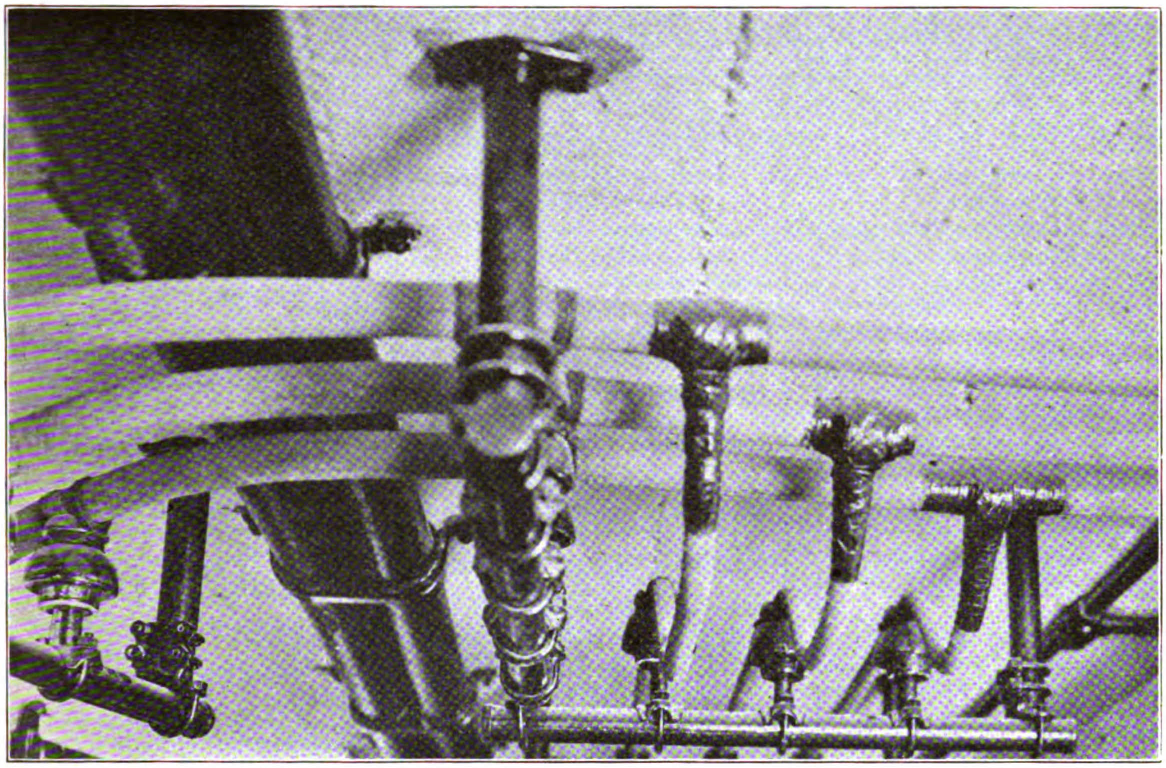
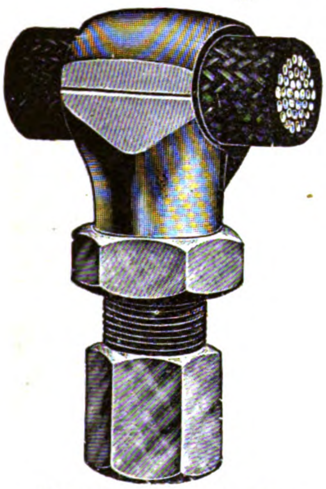


How Dossert Connectors Were Used By the C. M. & St. P. R. R.



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The cut above illustrates an installation of Dossert Connectors in one of the Chicago, Milwaukee & St. Paul substations in the electrified section.

It shows the 300,000 C. M. starting leads connected by means of Dossert Cable Taps to the 1,000,000 C. M. running leads of the 2,300 volt synchronous motor of the 2,000 K. W., 3,000 volt D. C. motor generator sets.

This railroad also uses Dossert taps to connect the D. C. feeder cables from the main switchboard to the trolley feeders at the point where the latter enter the substation buildings.

Substantial savings can be effected by the use of Dossert Connectors wherever cable connections have to be made, either in the power house, substation or on the feeder system. There is a type made to fit any ordinary joint, and we will design special connectors to meet unusual cases.

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Advertisements of equipment, supplies and materials, and other announcements that are deemed of interest to the membership of the Institute and other readers of the JOURNAL, will be published in the advertising section. All advertisers are entitled to listings in the classified Index of Advertisers. Rates will be furnished upon application.

Advertising copy should reach the publication office by the tenth of the month, for the issue of the following month.

The right is reserved to decline to publish any advertisement which the Institute authorities deem unsuited to the JOURNAL.

Suggestions for improvements in the advertising section are invited. All communications should be addressed to the Advertising Department, JOURNAL of the A. I. E. E., 33 West 39th Street, New York.

Classified Advertiser's Index for Buyers

A classified and comprehensive list of manufacturers and agents for machinery and supplies used in the electrical and allied industries; professional consultants and laboratories.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 10.

(Continued on page 8.)

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REG. U.S. PAT. OFF. & FOREIGN COUNTRIES.

Medal and Diploma
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"MADE IN AMERICA"
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"ELECTROSE" Insulators are standard with
UNITED STATES NAVY AND ARMY
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"ELECTROSE" is made up in a number of grades for various requirements, each grade possessing special characteristics.
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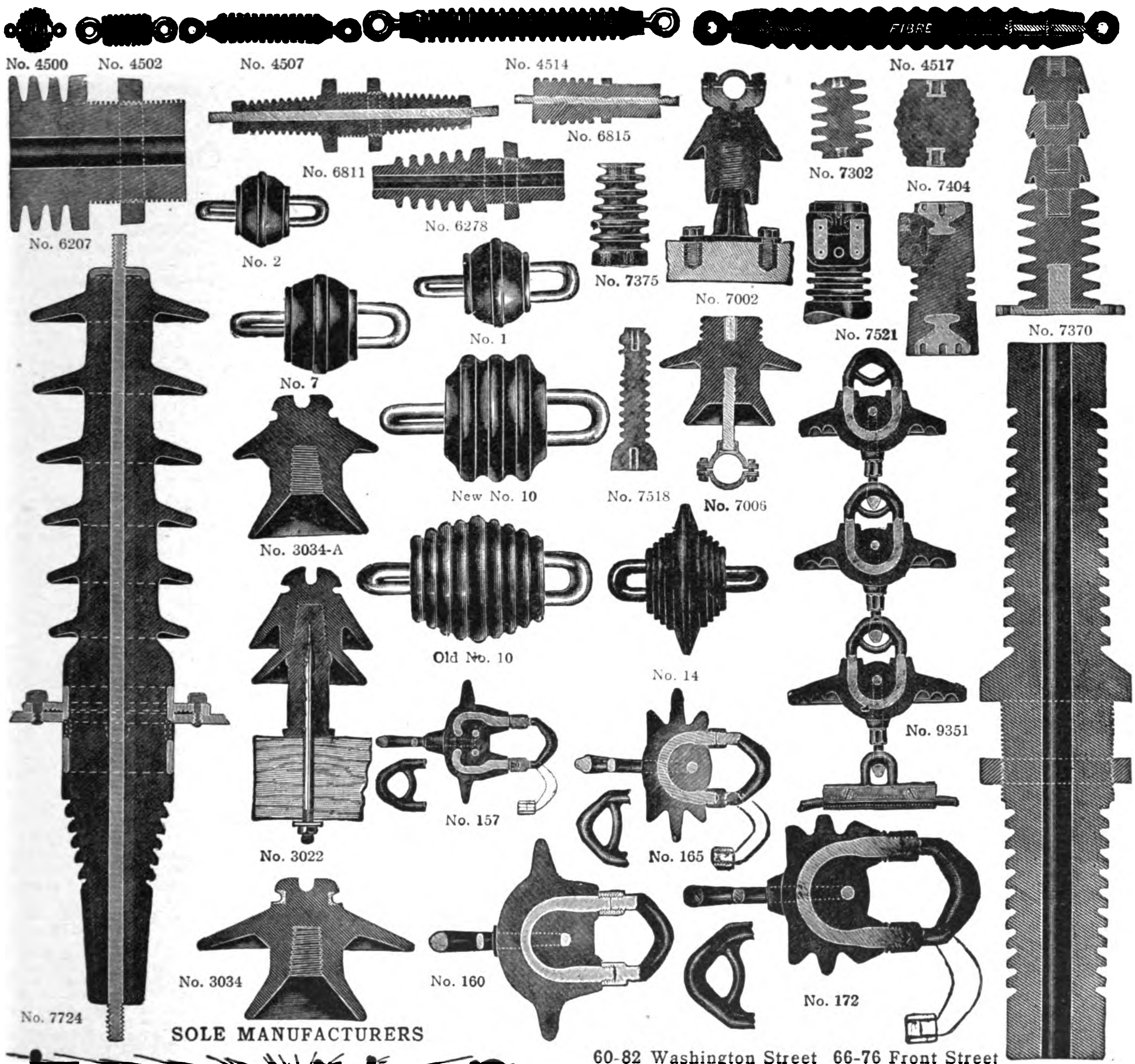

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ELECTROSE MFG. CO.

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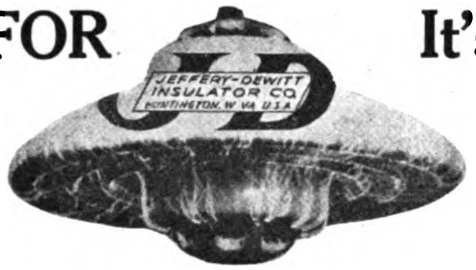
Classified Advertiser's Index for Buyers—*Continued.*

(Continued from page 6.)

The Merit Is Manufactured Into The Unit. Since The Merit Is In It, If You Miss It Whose Fault Is It? Whose Loss Is It?

NOW This RUGGED Insulator Demands Your Attention

FOR It's



Different

SO

It's Your Duty

to study this insulator directly.

As pioneers in the production of thick porcelain insulators of the unit type exclusively, many obstacles have been overcome.

As pioneers in the precise firing of insulators and in the development of successful methods for checking porosity, we deserve credit and we are adopting every practical method which ingenuity and enthusiasm suggest to guarantee the uniformly high quality of each unit produced.

The demand is constantly increasing but production has broken records too. J-D insulators have proven supreme in safely resisting puncture by lightning and other transient voltages, in safely resisting destruction by power arcs, in standing up under mechanical abuse, temperature changes and rifle bullets.

These things are all admitted or are easily provable by you. Why hesitate when you can get action and results? Visit our largest users and our plant and go home convinced.

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ALPHABETICAL LIST OF ADVERTISERS

(For classified list of Advertisers see Page 6.)

SCIENCE ABSTRACTS

Section A: Physics **Section B: Electrical Engineering**

Issued monthly by the Institution of Electrical Engineers, London, in association with the Physical Society of London. With the cooperation of the American Physical Society, the American Institute of Electrical Engineers, and the American Electro-Chemical Society.

The contents of the two sections are as follows:

SECTION A—General Physics; Light; Heat; Electricity and Magnetism; Chemical Physics and Electro-Chemistry.

SECTION B.—Steam Plant, Gas and Oil Engines; Industrial Electro-Chemistry, General Electrical Engineering, and Properties and Treatment of Materials; Generators, Motors and Transformers; Electrical Distribution, Traction, and Lighting; Telegraphy and Telephony.

More than 150 publications including Society Proceedings and other periodical publications, appearing in all parts of the world, are regularly abstracted.

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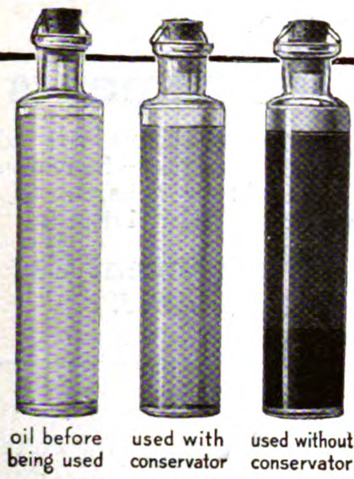
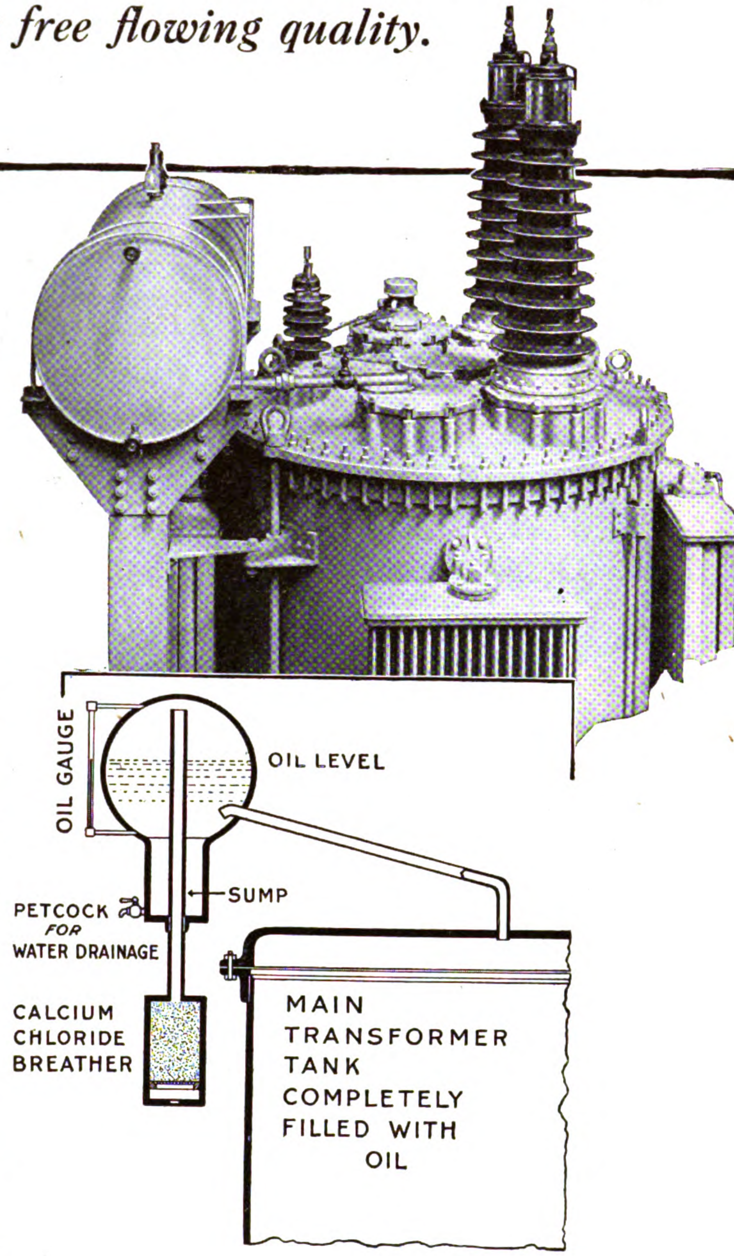
The first volume was issued in 1898. Back numbers are available, and further information regarding cost can be obtained upon application to

F. L. HUTCHINSON, Secretary,
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS,
33 West 39th Street, New York.

The Oil Conservator preserves the dielectric strength of transformer oil and its free flowing quality.





The Oil Conservator Transformer as developed by the General Electric Company consists of a main tank, containing the transformer, which is completely filled with oil, and an auxiliary tank for oil expansion. Connection between the two tanks is restricted so that there is no rapid interchange of oil and the temperature of the oil in the auxiliary tank is always relatively low. Any water that may be condensed in this auxiliary tank is collected in a "sump" and drawn off without coming in contact with the transformer, and main body of the oil.

What the Oil Conservator Transformer does

I. Eliminates "Breathing" and water condensation in main tank, thus maintaining the original insulating value of the oil.

II. Avoids the possibility of explosion by the ignition of a mixture of air and gas vapor from hot oil.

III. Practically eliminates oil decomposition or "sludging" as a result of exposure of hot oil to oxygen.

The General Electric Company offers the Oil Conservator Transformer as a standardized product with its value already fully established in the field and a factory equipment allowing of its economic application to practically all oil insulated "power" units of 500 Kv-a capacity and above.

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities

51-5

When you Consider the Instrument Question—

—you will realize fully what a high degree of efficiency and economy you can effect by selecting

Weston

ELECTRICAL

Indicating Instruments

As soon as you inspect them—even before you subject them to the test of comparison in actual use—the reasons for their acknowledged superiority will be apparent to you. These reasons are revealed in every structural detail.

Weston Electrical Instrument Co.
65 Weston Ave., Newark, N. J.
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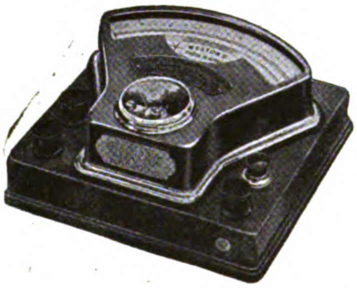
Model 1 D.C.
Portable Voltmeter



Weston Models include complete groups for Portable and for Switchboard Service on A.C. and on D.C. circuits, together with many instruments designed for special purposes. Write for particulars regarding your needs.

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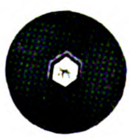
An extremely dense and tough insulator

VUL-COT fibre is especially adapted for all insulating parts that must also function mechanically.

The extra denseness and toughness of *VUL-COT* give it phenomenal wearing qualities even as compared with other fibres and they add enormously to its electrical resistance.

Then too it is much easier to drill, thread or machine generally, because its density is absolutely uniform—no soft or hard spots or fissures.



VUL-COT fibre comes in sheets, rods or tubes, or machined to special shapes and our booklet describes fully its countless electrical and mechanical uses.

AMERICAN VULCANIZED FIBRE CO.
516 Equitable Building, Wilmington, Del.

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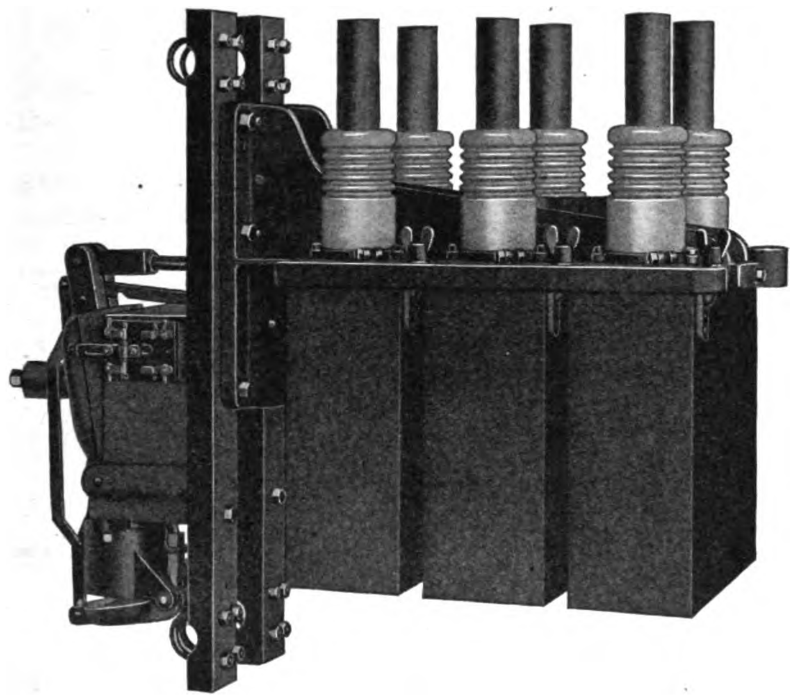
CONDIT

Oil Switches and Circuit Breakers

TYPE D-12



ELECTRICALLY OPERATED—PIPE FRAME MOUNTING
THREE POLE, 500 AMPERES, 15,000 VOLTS.

Condit Type D-12 oil switches and circuit breakers are invariably used to meet demands in controlling and protecting electrical circuits and apparatus where the pressure does not exceed 15,000 volts. They are especially adaptable where space is an important factor, and a relatively high interrupting capacity is desired.

They are *used* principally to control feeder circuits in substations of larger distribution systems and for the control and protection of generators and feeders in industrial service. They are furnished manually operated for panel-frame mounting and remote control for both manual and electrical operation.

Condit Type D-12 oil switches and circuit breakers are furnished in 2, 3 and 4 poles for all standard ampere capacities up to and including 1200 amperes.

If you are interested in the highest degree of protection for your equipment write for bulletin No. 418 at once.

Condit Electrical Mfg. Co., South Boston, Mass.

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WAGNER ELECTRIC MANFG. COMPANY

Wagner Quality

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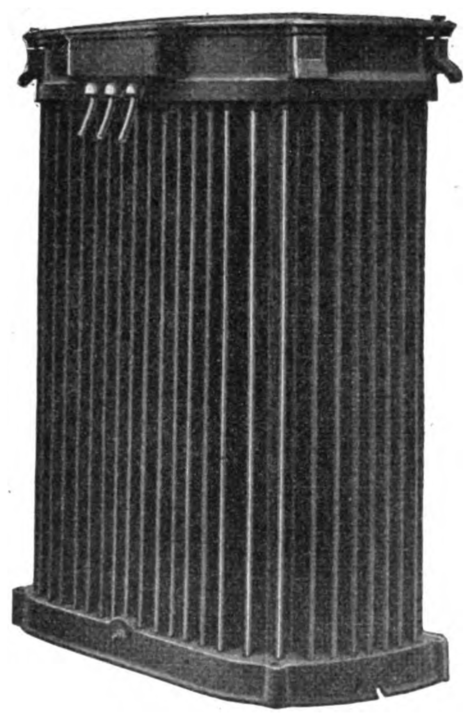

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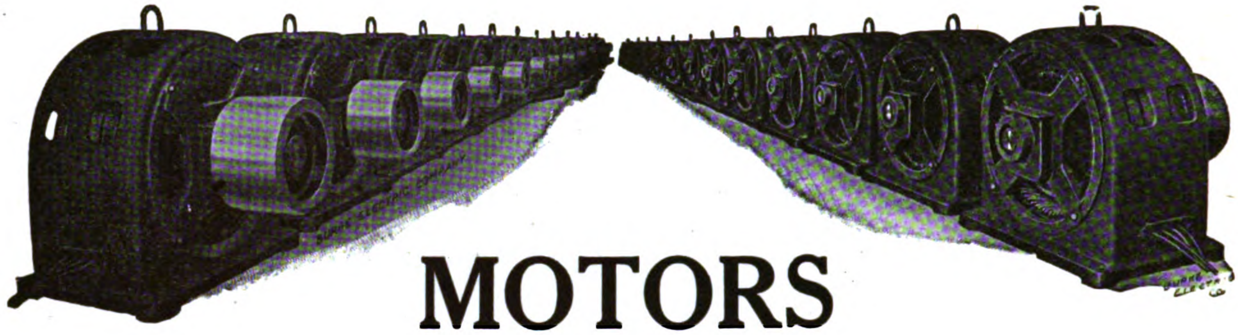

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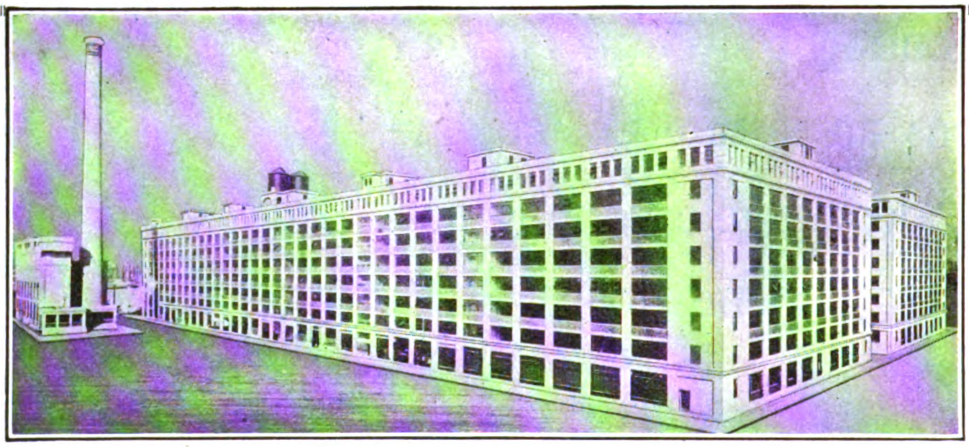

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12	1.588	1.619	1.650	1.682	1.713	1.744	1.775
10	0.9989	1.018	1.038	1.058	1.077	1.097	1.116
8	0.6282	0.6404	0.6527	0.6651	0.6774	0.6898	0.7021
6	0.403	0.410	0.419	0.427	0.435	0.442	0.450
4	0.253	0.259	0.263	0.268	0.273	0.278	0.283
2	0.159	0.162	0.166	0.169	0.172	0.175	0.178
1	0.126	0.129	0.131	0.134	0.136	0.139	0.141
0	0.100	0.102	0.104	0.106	0.108	0.110	0.112
00	0.0795	0.0811	0.0826	0.0842	0.0857	0.0873	0.0888
000	0.0630	0.0642	0.0655	0.0667	0.0680	0.0692	0.0705
0000	0.0500	0.0509	0.0519	0.0529	0.0539	0.0549	0.0559
Cir. Inches							
0.25	0.0423	0.0431	0.0440	0.0448	0.0456	0.0465	0.0473
0.35	0.0302	0.0308	0.0314	0.0320	0.0326	0.0332	0.0338
0.50	0.0211	0.0216	0.0220	0.0224	0.0228	0.0232	0.0236
0.75	0.0141	0.0144	0.0147	0.0149	0.0152	0.0155	0.0158
1.00	0.0106	0.0108	0.0110	0.0112	0.0114	0.0116	0.0118
1.25	0.00846	0.00863	0.00879	0.00896	0.00913	0.00929	0.00946
1.50	0.00705	0.00719	0.00733	0.00747	0.00760	0.00774	0.00788
1.75	0.00604	0.00616	0.00628	0.00640	0.00652	0.00664	0.00676
2.00	0.00529	0.00539	0.00550	0.00560	0.00570	0.00580	0.00591

(Continued)

Size A. W. G. or Cir. In.	55 C 131 F	60 C 140 F	65 C 149 F	70 C 158 F	75 C 167 F	80 C 176 F	85 C 185 F
14	2.872	2.922	2.971	3.021	3.071	3.120	3.170
12	1.806	1.838	1.869	1.900	1.931	1.962	1.994
10	1.136	1.156	1.175	1.195	1.215	1.234	1.254
8	0.7144	0.7268	0.7391	0.7515	0.7638	0.7762	0.7885
6	0.458	0.466	0.474	0.482	0.490	0.498	0.506
4	0.288	0.293	0.298	0.303	0.308	0.313	0.318
2	0.181	0.184	0.188	0.191	0.194	0.197	0.200
1	0.144	0.146	0.149	0.151	0.154	0.156	0.158
0	0.114	0.116	0.118	0.120	0.122	0.124	0.126
00	0.0904	0.0920	0.0935	0.0951	0.0967	0.0982	0.0998
000	0.0717	0.0729	0.0742	0.0754	0.0767	0.0779	0.0791
0000	0.0569	0.0578	0.0588	0.0598	0.0608	0.0618	0.0628
Cir. Inches							
0.25	0.0481	0.0490	0.0498	0.0505	0.0514	0.0523	0.0531
0.35	0.0344	0.0350	0.0356	0.0362	0.0377	0.0373	0.0379
0.50	0.0241	0.0245	0.0249	0.0253	0.0257	0.0261	0.0266
0.75	0.0160	0.0163	0.0166	0.0169	0.0171	0.0174	0.0177
1.00	0.0120	0.0122	0.0125	0.0127	0.0129	0.0131	0.0133
1.25	0.00962	0.00979	0.00996	0.0101	0.0103	0.0105	0.0106
1.50	0.00802	0.00816	0.00830	0.00844	0.00857	0.00871	0.00885
1.75	0.00687	0.00699	0.00711	0.00723	0.00735	0.00747	0.00759
2.00	0.00602	0.00612	0.00622	0.00633	0.00643	0.00654	0.00664

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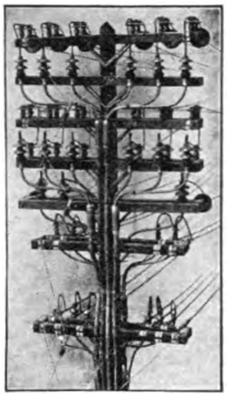

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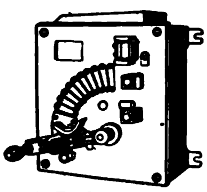

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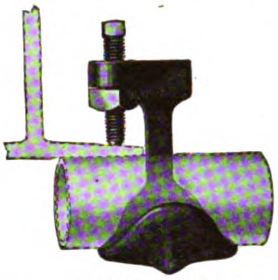

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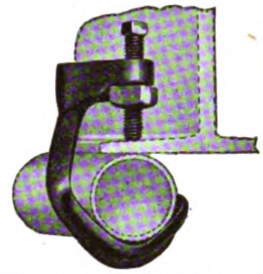

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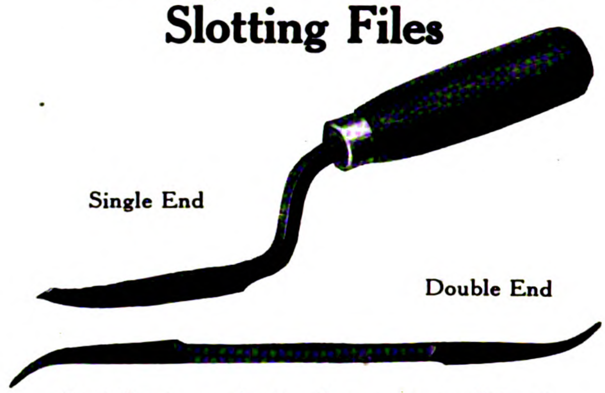

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Standard Graphic Symbols

BY EDWARD J. CHENEY

Chief, Div. of Light, Heat and Power, Public Service Commission, Albany, N. Y.

Symbols have been in vogue since the early ages and are particularly useful to the electrical engineer. Those now in use are the result of growth and evolution and there is no uniformity or agreement. It is desirable to standardize them as far as possible in order to afford simplicity and general usefulness, but it is suggested that the Institute undertake for the present to standardize only those symbols which would be most general and widely used. The general principles which should govern selection are discussed, and there is given a list of suggested symbols covering some of the most important items. These are offered for criticism and suggestions in order to assist toward definite standardization.

WHEN primitive man succeeded in transferring thought between two individuals beyond sight and hearing of each other, one of the first means was by symbols, or crude and roughly cut representations of objects. The limitations of the method need not be dwelt upon. Today, by the manipulation of twenty-six letters and ten figures into countless combinations, we can express upon the printed page anything which language may convey, but still we find the method of our ancestors most convenient in many instances. Particularly in the diagrammatic sketches which are at once a convenience and a necessity to the electrical engineer, do we need to use and understand simple, easily made, and readily recognized symbols for the machines, instruments, and devices whose connections and uses we portray.

In these days, as never before in the world's history, it is unnecessary to argue the desirability of uniformity; of national and international standardization of all things connected with industry. To state the proposition is to have it accepted. Symbols constitute a language, and the more that language can be simplified and the broader its field of recognition, the greater will be its usefulness. We have the language, but there are many dialects; it may almost be said that there are many languages; and if the occurrence at Babel can be reversed, something will be added to the effectiveness of human endeavor.

A sub-committee of the Standards Committee, composed of Dr. P. G. Agnew, Mr. W. A. Merrill, and the writer, assisted by the effective co-operation of many particularly interested and informed engineers, have been investigating the possibility of bringing some degree of order out of this confused situation. It was first attempted to collect and tabulate the symbols used in this and other countries, with the idea that perhaps this alone would solve the problem by disclosing a weight of preference which could be accepted. The result was both instructive and confusing. It was found that there were plenty of symbols; almost every conceivable thing has been symbolized by some one, and most things by many; but of agreement there was very little.

Symbols now in use have been evolved as need arose. In most cases they have attempted to represent the thing indicated closely enough to enable identification. This accounts for much of the confusion, as devices of the same class are so varying in appearance. It also accounts for much of the complication, the attempt to portray the object frequently resulting in something more like a picture or a working drawing than a true symbol. Slight variations in type or appearance are indicated by corresponding changes in the symbols, and in many instances the results are not, and never will be, interpreted except by the few initiated. In justice it should be said that some are so widely used as to be generally recognized, and these afford a foundation upon which to build. It should also be said that there has been found no reactionary desire to cling to the particular symbols now used, but on the contrary there is a generally expressed willingness to accept any thing upon which there can be general agreement.

There is practically no limit to the things which can be symbolized, and one of the first questions is to define the Institute's scope. Obviously the adoption of too many symbols would approach the situation of Chinese writing; only the specially trained would be able to interpret, and the aim would be defeated. There is also grave question whether the Institute is warranted, for the present at least, in going into special fields, or dealing with anything except of general application. It is believed that the Institute might properly standardize such symbols as will be used in papers which are presented to it, or in connection with diagrams of a general nature; but should not, unless by agreement with the interests affected, try to fix all symbols needed for special fields, such as full connection diagrams for switchboards, control equipments, or telephone, telegraph and radio apparatus. The National Electrical Contractors' Association, for instance, has a set of standard symbols, extremely useful to them, and regarding which they are unquestionably the best judges. It is to be hoped, of course, that the various special fields will use the standard general symbols and co-ordinate their special symbols with them.

It is suggested that the symbols included in a stands ard list should conform to the following principle- so far as possible:

a. Be adapted to universal use.
b. Be simple and easily made.

To be presented at the 8th Midwinter Convention of the A. I. E. E., New York, February 18, 1920.

c. Be flexible; *i.e.*, permit indication of as many things as possible without additional symbols and permit simple modifications or extensions for special cases.

d. Be indicative in appearance.

e. Be those most used at present.

In order to elicit suggestions and criticisms the list of symbols shown in Plates 1, 2 and 3 are presented as conforming to the foregoing principles and covering some of the most important items.

1. *Conductors.* It is rather common to show conductors crossing, but not connected, as in Fig. 1, but this makes the construction more difficult and seems unnecessary. The absence of a dot should be sufficient indication that there is no electrical connection.

Fig. 1

2. *Earth Connections.* This is quite generally used and seems to be satisfactory.

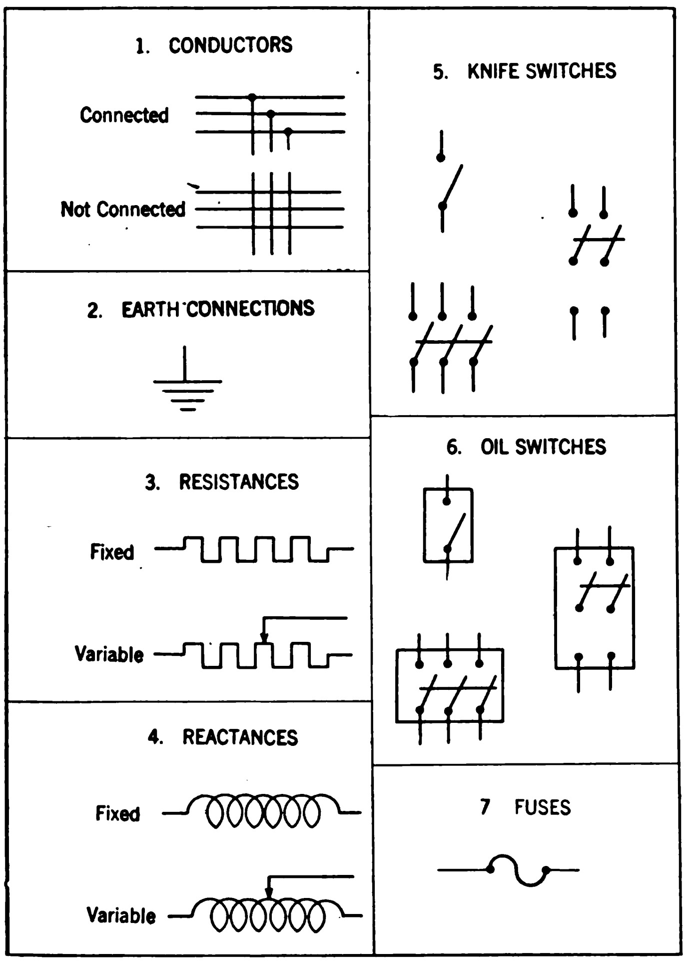

Plate 1

3. *Resistances.* 4. *Reactances.* 9. *Windings.* These three should be considered together because of the way they are confused in current practise, although it is important that they should have distinctive symbols. At present the zigzag line (9) is used rather indiscriminately to represent all three. The rectangular line (3) is frequently used for resistance (sometimes for iron grid resistance only), but never for anything else, and seems to meet all requirements for a resistance symbol.

The succession of loops (4) is indicative of reactance and is widely used for that purpose in text books and elsewhere. Apparently the only objection raised against it is its alleged difficulty of construction. Its construction can be made difficult, but need not be. The loops in Plate 1 are drawn with one sweep of a compass, 5/6 of a circle being drawn about each center except the end ones. No spacing is necessary; each new center is placed by eye just far enough outside the preceding arc to allow for the ink line. Drawn in this manner, which was independently developed by Mr. J. P. Buckley but apparently by others also, the looped figure is easier to construct than either of the others.

This leaves the zigzag line to denote windings of all kinds, thus the three as shown are submitted as a solution of perhaps the most perplexing of the problems involved.

5. *Knife Switches.* 6. *Oil Switches.* The convention for knife switches will probably be generally accepted, but the indication of an oil switch by putting a rectangle around the corresponding knife-switch symbol is probably novel. The advantages of the system are fairly obvious.

The English indicate live and dead sides of a switch by having the conductor terminate in an open circle at the dead side and in a full dot at the live side, but this makes construction difficult, may sometimes be misleading, and seems to be an unnecessary complication.

7. *Fuses.* This is the old symbol, designed, apparently, to represent a wire of soft metal twisted around two binding posts. Cartridge fuses are commonly shown as in Fig. 2 but this is not sufficiently general. The symbol shown on Plate 1, constructed with two half circles, is easy to make and quite distinctive.

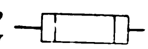

Fig. 2

8. *Circuit Breakers.* Existing symbols are mostly sketches of some particular type of breaker. The symbol suggested will probably be generally recognized, is sometimes used now, and is distinctive.

10. *Transformers.* The symbol for transformers will naturally follow if (9) (for windings) is accepted. Of course there ought to be further elaboration to permit indication of polyphase transformers and different bank connections, but that has not been undertaken as yet.

11. *Rotating Machines.* A circle, with conductors coming to the periphery, is used as the general symbol. Small rectangles, representing brushes, will indicate direct-current machines. Letters inside the circle will give any additional information desired. Mechanical connection is shown by a line joining the centers.

12. *Meters and Instruments.* This is the same as

for rotating machines except the conductors will come to dots inside the circles.

13. *Shunts.* This is the symbol generally used. Sometimes the shunt circuit conductors are brought to a separate set of dots as in Fig. 3, but this seems to be an unnecessary complication.

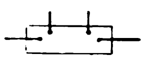

FIG. 3

14. *Relays.* A confusing multitude of symbols is now in use. The system suggested is uniform with that for machines and meters except that a rectangle is used.

15. *Batteries.* The general symbol is that commonly employed but it seems desirable to differentiate between primary and secondary batteries, and the suggestion is to put a rectangle around the "plates" to indicate a storage battery.

In using this symbol it ought to be understood that the long, thin line is the positive terminal, and this convention should be rigidly adhered to whenever polarity is of importance.

16. *Lamps.* These are almost universal.

17. *Condensers.* This is the most commonly used symbol and seems to meet all requirements.

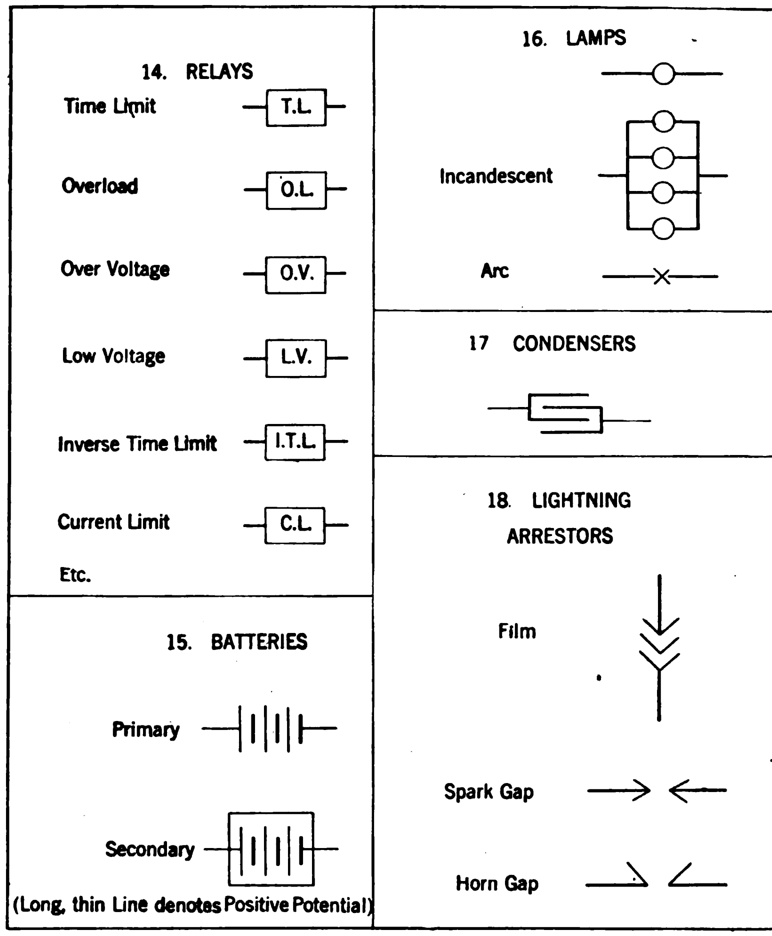

PLATE III.

18. *Lightning Arresters.* There are many types and many symbols. The three symbols shown will doubtless be readily recognized and cover the most general cases.

CONCLUSION

After all interests and all views have been fully considered, it is suggested that this group of symbols, modified as may appear advisable, should be included in the standards of the Institute, there to be added to from time to time as occasion warrants. It will, of course, be desirable to secure as much international agreement as possible. In this connection it should be said that the practise of other countries has been given full weight in determining the symbols herein suggested.

The author is indebted to his fellow subcommittee members and to many others for suggestions, and it is hoped that this paper will arouse general interest and bring forth criticism and constructive suggestions which will enable definite decisions to be reached at an early date.

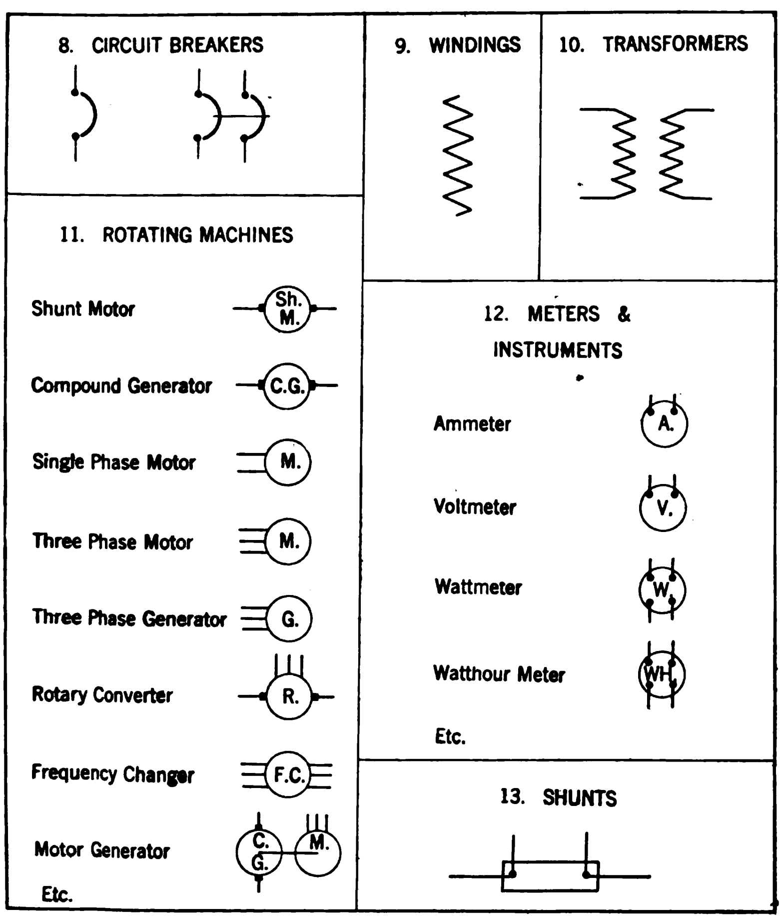

PLATE II.

The Measurement of Projectile Velocities

BY PAUL E. KLOPSTEG
Physicist, Sales Department, Leeds and Northrup Co.
AND
ALFRED L. LOOMIS
Formerly Major, Ordnance Dept., U. S. A.

The paper discusses the requirements imposed by proving ground practise upon a chronograph which is intended for general ammunition testing. Instruments of the standard pre-war pattern were entirely inadequate in number for testing the immense quantities of ammunition contracted for by the Government during the war. The development work undertaken to cope with the whole problem of velocity testing was first directed towards devising methods for speeding up measurements with the existing instruments. Conditions made it necessary to lay aside this work and concentrate upon the development of a totally new device for obtaining the results both speedily and accurately. The instrument which was developed, and adopted as a standard ordnance chronograph, is designated "Aberdeen chronograph." An account of its development is given. It is an assembly of many standard parts, with a few necessary special ones. Rapid production of the instruments was thereby made possible. The Aberdeen chronograph, and the procedure in determining velocities by this means, are described in detail. For the sake of comparison, the Boulengé chronograph is briefly described. Comparative results as to speed and accuracy of measurement are given.

Introductory

One of the very important measurements which must be made at an army proving ground is that of projectile velocity. Not only is it essential that such measurements be made, in connection with ammunition testing and development, but it is equally essential that the results be reliable. Data of the greatest accuracy are needed in certain problems of experimental development. Velocity measurements for the computation of range tables must be as free from error as possible. In making powder tests, seven "uniformity" rounds are fired; the measured velocities, for acceptance of the powder, must agree within narrow limits. Rejection of a lot usually means the rejection of thousands of dollars' worth of material.

The difficulty of making these speed tests is increased by the fact that the portion of the flight of a projectile with which we are directly concerned, is an extremely transient phenomenon. The interval during which the shell lends itself to the measurement is of the order of hundredths of seconds. This fact adds a third difficult requirement to the two above mentioned, namely, certainty of obtaining the record when the projectile passes. Failure to do so necessitates the firing of an extra round, sometimes at a cost of hundreds of dollars. During the emergency there were several additional requirements. The apparatus had to fulfill the demand of giving good results day after day, under all conditions of weather, and this in the hands of operators without technical training.

It was recognized in the early summer of 1917 that when deliveries of the immense quantities of ammunition contracted for by the government would commence, the matter of making the necessary velocity tests quickly and accurately would prove an embarrassing problem. The existing chronographs, of the Boulengé pattern, were limited in number, and manufacture of enough of these instruments in time to meet the situation was, because of their mechanical complexity, out of the question. In order to represent adequately what the problems were and how they were met, we shall first make brief mention of some of the characteristics of the Boulengé chronograph. A fuller description is contained in War Department Circular No. 1682, and in the 5th edition of Foster's Handbook, page 1128.

In all the various practical instruments devised for velocity determinations, the measurement is that of the time interval required by the projectile to traverse a measured section of its path. With the Boulengé chronograph, this section is included between two wire screens, the breaking of which by the projectile actuates the recording mechanism. The latter utilizes two electromagnets, each in series with one of the respective screens. These magnets, by virtue of the current through them so long as the screens are intact, support, respectively, a rod to receive the record, and a weight, to release a marking "knife" by falling upon a trigger. The rod and weight are intended to fall freely under the action of gravity. The origin of readings on the rod is the mark made by the knife when the rod is suspended. A simultaneous break of circuits of the two magnets, produced by a device called a disjunctor, produces a second mark, somewhat higher up, which represents the time required by the instrument to function. When the projectile is fired through the screens, it breaks, first, the circuit of the magnet supporting the rod, then that of the circuit supporting the weight, thus making a third mark, still higher up on the rod. Measurement of the distances from the origin of readings to the two other marks mentioned gives the data from which the time interval may be turned up in tables. From the interval so found, the velocity is determined by the usual formula.

For the sake of a later comparison, statements should be made as to the accuracy, and as to the best conditions for precision of measurement with the Boulengé chronograph. Cranz in his "Lehrbuch der

To be presented at the Midwinter Convention of the A. I. E. E., February 19, 1920.

Ballistik"—which is probably the most authoritative work on ballistics yet produced—states that a given Boulengé chronograph is capable of repeating its reading of a certain time interval to 0.0001 second; but that, because of certain constant errors, which are very difficult to avoid or to determine with certainty, the absolute value of the time interval as measured by the instrument is, at best, reliable to 0.001 second. This statement is fully borne out by experience. The interval most favorable for precision of measurement being about 0.11 to 0.12 second, the distance between screens should be variable so that the distance best suited to a particular gun may be used. With the 155 mm. gun, for instance, this distance is 200 feet; on account of the blast, the first screen is placed about 100 feet from the muzzle. As a result, the second screen must be very high, even with moderate elevations of the gun. Thus, with an elevation of but thirty degrees, the second screen must be about 175 feet above the level of the gun. It is needless to point out, perhaps, that a movable screen support which can rigidly hold a screen at a height of 175 feet, has not yet been built. Even were this possible, the time consumed in hauling down a screen from a height of 175 feet, repairing or replacing it, and hauling it up again, would be so considerable as to render rapidity of testing quite impossible. The immediate remedy may be sought in a greatly shortened screen distance. In this case, of course, a more accurate recording instrument would be desirable.

In addition to the undesirable feature of requiring so much time for replacement, the wire screens have another serious drawback, which has repeatedly been mentioned in the writings of the Germans, the French and others upon the subject, and which thrusts itself upon the attention of anyone making a careful study of them. This is the very considerable uncertainty as to whether the recorded interval actually and accurately corresponds to the interval taken by the projectile to travel the measured distance between screens. The uncertainty is due in part to persistence of contact of the wires with the projectile, even after they are broken; in part also to the fact that the instant of break depends somewhat upon whether a wire is squarely hit by the tip of the projectile, or whether the tip strikes through the screen between neighboring wires. It happens occasionally—in spite of the fact that the wires are ordinarily spaced about one-third of a caliber apart—that the projectile slips through the screen without breaking a wire.

With the idea of eliminating the wire screens as the signaling end of the Boulengé arrangement, one of the writers in the summer of 1917 presented to the Sandy Hook Proving Ground a plan for "wireless" screens which had occurred to him some months before, in connection with other work upon the measurement of short time intervals upon which he had been engaged. Essentially, a screen of the type proposed was to be a mutual inductance coil of sufficiently large diameter to permit firing a projectile through it without great risk of injuring the windings. If a steady magnetic field is set up within such a coil by a current through one of the windings, it follows that any sudden disturbance of the field—by the passage of a projectile of magnetic material, for example—will produce a corresponding momentary electromotive force in the other winding of the coil. Preliminary tests showed the supposition to be correct.

For the purpose of developing this idea into a routine method, and to work upon other related problems, one of the present writers entered upon work at the Sandy Hook Proving Ground as Electrical Engineer in the Ordnance Department. The preliminary work was carried on at the Bureau of Standards, where facilities were kindly offered, and where much splendid cooperation was given, particularly by Dr. P. G. Agnew and Mr. W. H. Stannard. At the same time other possible solutions of the problem of speeding up the tests were being considered, and apparatus was being built. Frequent trips were made to Sandy Hook for field tests, which had to be made under very adverse conditions on Saturday afternoons and Sundays, so as not to interfere with routine firing.

The inductor scheme as partially developed was put to actual test, with very promising results; the Boulengé chronograph used with two such coils to all appearances functioned in the same manner as though the projectile had broken the usual type of wire screens. Unfortunately the work had to be discontinued before the development could be considered through the experimental stage, because of the removal of the proving ground from Sandy Hook to Aberdeen, Md. Here experiments with the coils became prospectively impossible for some months, and the work was concentrated upon another device which seemed to hold considerable promise, and with which tests could more readily be made. This device had been constructed at the Bureau of Standards for the purpose of recording signals produced by the "bow wave" of the projectile. The instrument which was finally evolved was called the Aberdeen chronograph. Work upon the inductor screens was not resumed because the newly developed instruments met all the needs which necessitated the development work, and their rapid production, as well as other problems occupied attention until the close of the war. It has been reported recently, however, that the inductor method is being applied with success in England.

Development of the Aberdeen Chronograph

The device mentioned in the preceding paragraph consisted of a Leeds & Northrup governed motor, on the vertical shaft of which was mounted a flywheel with a smooth rim. A strip of paper could be fastened upon the rim to receive the records produced by the projectile when it actuated the signaling device. Up to this point the instrument differed from previously

described ballistic chronographs only in that a constant speed motor was used. All such chronographs, however, utilized the breaking of wires for the signals,

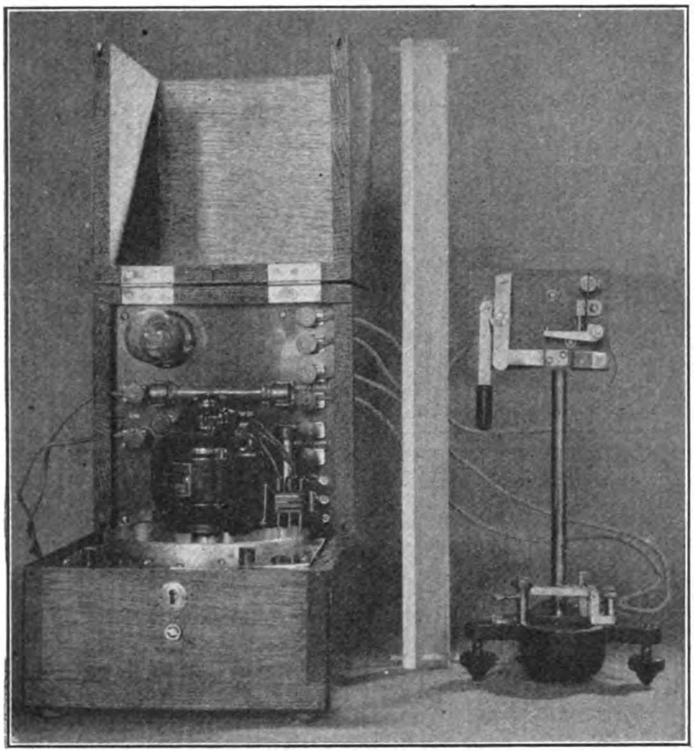

Fig. 1—Aberdeen Chronograph, Fall Apparatus and Direct-reading Velocity Scale. Instruments in Operating Position.

the interruption of the current producing a spark from a point in close proximity to the rapidly revolving drum. In this case, the recording system was designed for open circuit operation, *i.e.*, the spark was to occur when a circuit was closed by the projectile. In connection with such circuits, it had been planned to use automatic contacts which should close when the bow wave of the projectile impinged upon them. The task of constructing such switches so that they would operate unfailingly and under all conditions proved formidable. The greatest possible speed in getting something usable remained imperative, and the urgency became greater as time passed.

It then occurred to one of us to try a new form of screen, or better, a form of contact target, in which contact should be established mechanically by the tip of the projectile. This target in its simplest form consists of a pair of metal sheets, of suitable thickness, separated by an insulating layer. Experiments immediately demonstrated the success of such an arrangement. Thus, the recording mechanism arranged for "make" circuit signals, together with the contact targets, became a most promising basis for further work of development.

On March 2, 1918, a modified design of the Mark I instrument* was taken to the Leeds & Northrup Company, and on March 15th three of the new Mark II instruments had been completed and were ready for operation at Aberdeen. These three instruments were used daily in routine measurements, in a shanty of rough boards on the gun platform, and so successful were they that it was decided to proceed immediately with the construction of the instruments in quantity. A new design, Mark III, including valuable suggestions from the manufacturers, was worked out which, with the exception of minor details, became standard. In these, of course, the faults revealed by experience with the Mark II instruments were eliminated. Much experimenting in the laboratory and under service conditions was carried on in the meantime on both the electrical and mechanical components of the apparatus. Several further improvements were made, and from this point the production of Mark IV Aberdeen chronographs in lots of 25 proceeded without delay.

An important factor in the success of the Aberdeen chronograph in the emergency, aside from questions of its excellence as an instrument, was the fact that from the time production began until the last instrument needed had been delivered, the average rate of production per working day was one complete instrument. This became possible, even with manufacturing facilities already overtaxed, because the design included many standard parts.

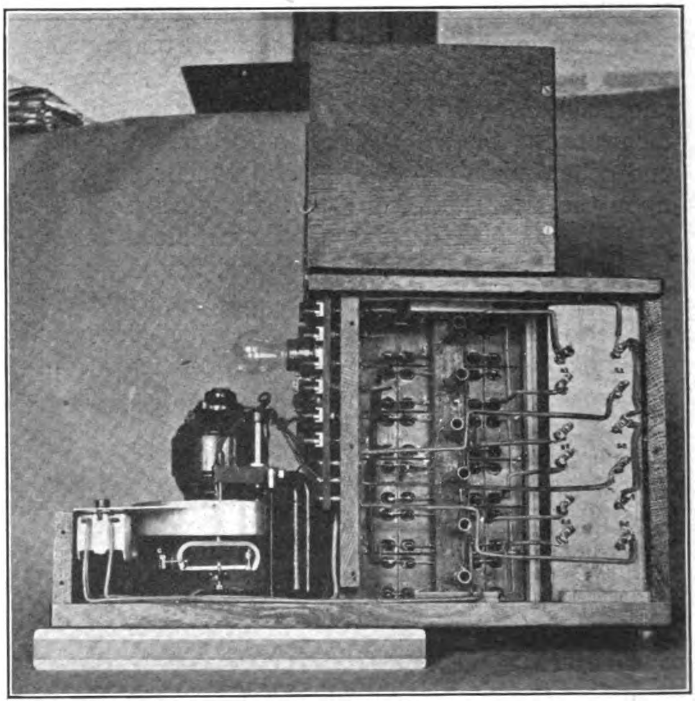

Fig. 2—Aberdeen Chronograph, Side View, with Case Opened for Inspection of Parts

Description of Mark IV Aberdeen Chronograph

Fig. 1 shows the chronograph ready for operating, and Fig. 2 is a side elevation, with the case open for inspection of the circuits. The size of the apparatus

*Mark I, Mark II, etc., is the War Department designation of successively developed types of ordinance material.

may be judged by comparison with the 12 inch scale, shown in the latter view. In Fig. 3 the case of the chronograph is shown closed, with the carrying handle attached.

The mechanical part of the device is seen by reference to the photographs to consist of a shallow cylindrical drum of aluminum, mounted on the vertical shaft of a small (110 volt direct current) motor. On the lower end of the same shaft is carried the constant

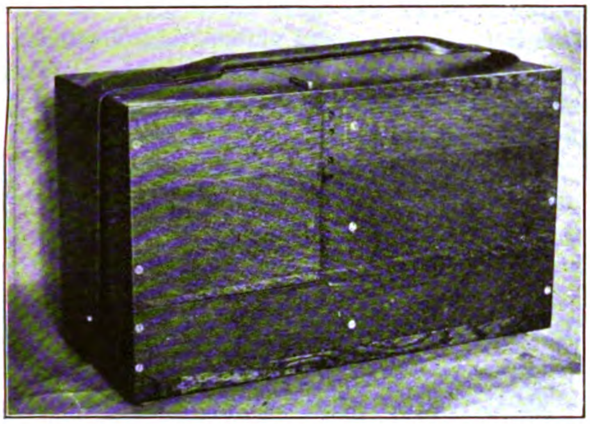

Fig. 3—Chronograph in Closed Case with Carrying Handle

speed governor, upon which depends, in large measure, the accuracy of the instrument. It is a development of the governor used in the Leeds & Northrup temperature recorder. The function of the governor is to control the power input into the motor. Its *modus operandi* may be understood by reference to Fig. 6. A thorough analysis of the device resulted in the design illustrated, which is capable of holding the speed so constant that the mean deviation from average speed, as determined in repeated tests over a fixed 0.2 second interval, was less than 1/10 per cent. Another way of representing this fact is in showing the results of a series of observations. Taking 100 measurements of a 0.2 second interval, 62 were within 0.04 per cent of average speed; 70 within 0.05 per cent; 77 within 0.06 per cent; 95 within 0.07 per cent; 97 within 0.08 per cent; and 100 within 0.09 per cent. In these measurements, therefore, it is safe to assume a maximum probable error of ± 0.1 per cent. A speed of 25 rev. per sec. is thus maintained; the method for checking this value will be described later.

A specially prepared strip of paper receives the record marks. The paper, which is blue, has a thin coating of white paraffin on one side. When a spark passes through the paper, it not only perforates the latter, but also melts a tiny bit of the paraffin, leaving a bright blue, easily distinguishable spot. The width of the strip is equal to the depth of the cylindrical drum, and its length to the inner circumference of the drum. It is held in position very firmly against the smooth inner surface of the drum, on account of the rapid rotation of the latter. By this arrangement, much saving of time is effected, since the record strip may be easily inserted in the drum, and, with a little practise, removed while the motor is running at full speed. With the speed mentioned, and an inner circumference of the drum of 500 mm., the paper strip is given a linear speed of 12,500 mm. per second. Thus a very open and uniform time scale is secured. Three spark points (Fig. 6), in the same vertical line, are held within 1 mm. of the record strip by an insulating block. A spring latch holds the points either in the recording position or at some distance from the paper.

Reference to Fig. 6 shows that one of the electrical spark-recording units consists essentially of a condenser, and the primary of a transformer, both in a circuit with the contact target. Up to the instant of firing, the condenser is kept charged through high resistances, from the supply line which furnishes the power for the motor. The supply line of 110- or 220-volts direct current, is connected at AB. When the tip of the projectile strikes the target, contact is established between the plates, and a discharge passes through the transformer resulting in a spark from the corresponding recording point. The main condenser has a capacity of 10 micro-farads. Later work showed

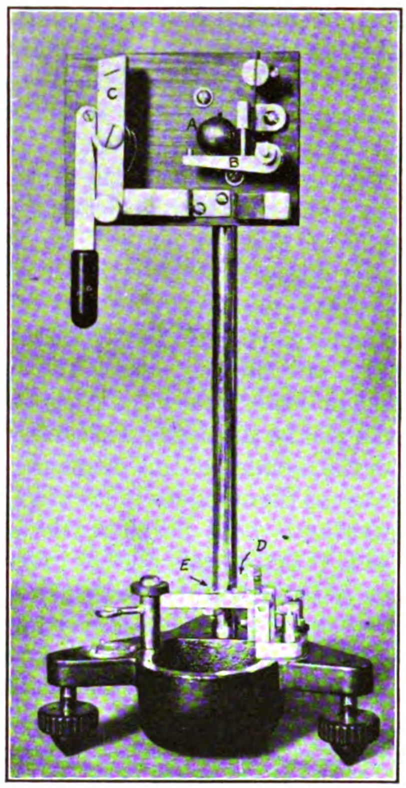

Fig. 4—Fall Apparatus for Verifying Accuracy and Constancy of Motor Speed

that an auxiliary condenser of 6 microfarads, connected in parallel with the plates of the contact target, greatly intensified the spark. The complete circuits are shown in the diagram. Three recording units were provided, as shown. Normally two only were

used, the third being for emergency, or for use in cases where average velocity values over two adjacent sections of the trajectory were to be determined on the same instrument.

A ready means for verifying the speed of the rotating drum is essential, to give the operator confidence in the performance of his instrument if for no other purpose. If we could, in some manner, produce two sparks, separated by an accurately-known short interval of time, we should have a ready means for checking the accuracy and constancy of the motor speed. A device which could be utilized for this purpose had previously been worked out in connection with psychological time measurements.* This is a "fall apparatus," the modified form of which for use with this chronograph is seen in Fig. 1, and shown in detail in Fig. 4. A ¾-inch steel ball *A* rests upon a spring-supported horizontal lever *B*. When the counterpoised hammer *C* which is under spring tension is released, it strikes the end of the lever a smart blow, knocking it clear of the ball. At the instant of striking, the contact between the hammer and lever produces a spark from, say, the uppermost spark point in the drum. Simultaneously the ball begins to fall. When it reaches the bare wire *D*, held on an insulated post, it makes a wiping contact with the latter, and then touches the tungsten plate *E*, between which and the wire it closes the second circuit. At the instant contact is made at *E*, a second spark jumps, say from the next lower spark point. Obviously we may adjust with great exactness the distance between the lowermost point on the ball, when it is in position on the upper lever, and the plate *E*, so that the time of fall between these two points is 0.2 second. This corresponds to five revolutions of the drum. If the speed of the latter is correct, two marks will be found upon the strip, one directly above the other. With slightly higher or lower speed than the correct value, the two marks will be displaced with reference to each other. From the amount of this displacement the constant error in speed becomes easily known. Thus, when the fall apparatus is kept permanently connected as shown in Fig. 1, it is a simple matter at any time during the course of the day to calibrate the chronograph. In practise, the speed remained so constant in a day's run that calibrations were made only two or three times during the day.

Fifty feet was chosen as the standard distance between targets for all velocities from 500 to 2500 feet per second. With a fixed distance between the contact targets, and fixed speed and dimensions of the drum, there is a one-to-one correspondence between distance between record marks and velocity. Thus it becomes possible to construct a direct-reading scale for velocities which is suitable for all the values between the limits mentioned. The scale was so designed that, when the shot was fired, regardless of the relative positions between the spark points and the abutting ends of the record strip, the velocity readings could be made without possibility of mistake. The scale is shown in Fig. 1, and again in the photograph of the accessories case (Fig. 5). This picture also shows the fall apparatus taken apart and in the case.

In its contact target arrangement, already described, the Aberdeen chronograph is unique among the ballistic chronographs. The fact that the recording spark occurs when the tip of the projectile establishes contact between the metal plates has the consequence that the otherwise great uncertainty in the distance between the points at which the signals occurred is practically eliminated. It may here be repeated that such uncertainty is probably the chief point of weakness, so far as accuracy is concerned, in the ordinary wire screens used with the Boulengé chronograph. That such errors are truly minimized with the contact targets is shown by the fact that the distance between targets could be reduced to 25 or 30 feet without seriously affecting the agreement among several instruments measuring the same time interval.

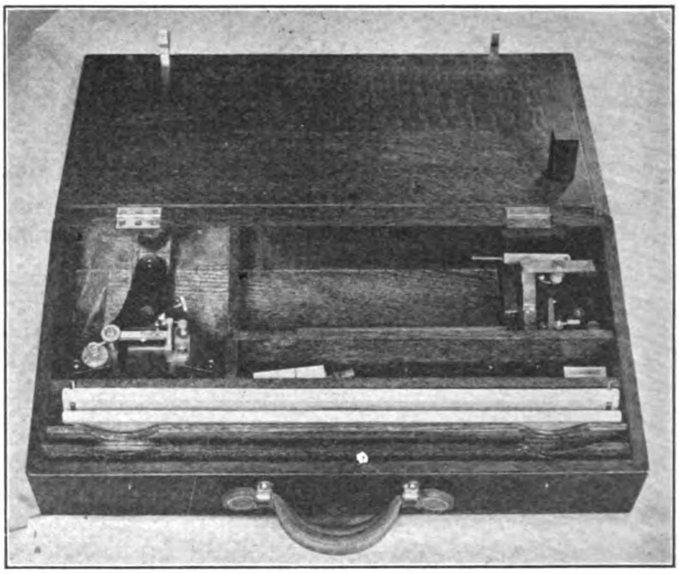

Fig. 5—Accessories Case with Necessary Auxiliary Apparatus

Procedure in Velocity Measurements

The application of the Mark IV chronographs to velocity measurements in such a way as to secure the data with minimum loss of time was in itself a development problem. Three instruments were used with the same pair of contact targets, and the observations were independently made and entered in the data book by three respective observers. The averages were then entered in a fourth book, together with the necessary accompanying data as to the gun, kind of projectile, etc.

The contact targets were made up beforehand in quantity. For the three-inch guns they consisted of lead

*Klopsteg, *Journal of Experimental Psychology*, II, 253, 1917.

foil strips about 3-in. by 12-in. which were attached with hot paraffin to the opposite sides of a sheet of paraffined building paper 5-in. by 17-in. Much of the routine firing was done with constant elevation of the guns, so that permanent supports for the screens could be used. These supports consisted of uprights, each of which had two cross-arms at the proper height, extending out on one side. The lower cross-arm was provided with a spring clamp, on the insulated inner surfaces of the jaws of which there were contact buttons which made connections with the lead foil sheets. The upper arm also carried a clamp which supported the contact target in a vertical position, and between the two clamps the target was held with sufficient firmness to prevent its being moved appreciably by the wind. From the contact buttons on the lower clamp, tion figure for "reduction to muzzle"* and for motor speed is added, and the corrected reading put down. All this is about a half minute's work. In the meantime, the detail of men outside has replaced the screens and reloaded the piece, and the next shot may be fired. In this manner velocities could be measured at an average rate of one round per forty-five seconds, or from three to five times as rapidly as by the older method. The advantage of speed of measurement is indicated by the fact that, although the Aberdeen Proving Ground was not established until January, 1918, and the new chronographs were not put in regular service until June, seventy per cent of all velocity measurements made at the Aberdeen Proving Ground before the cessation of hostilities, were made with Aberdeen chronographs.

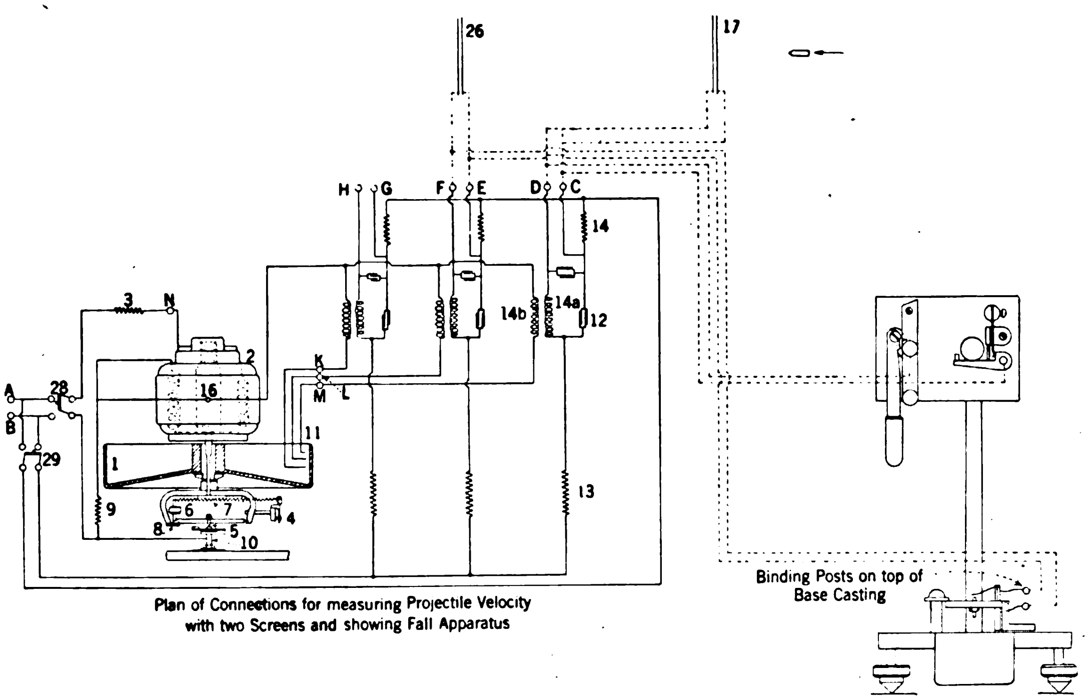

Fig. 6

wires were run in conduit to the instrument building, just behind the gun platform.

In undertaking a series of measurements, the motors are started running, and their constancy and accuracy of speed verified by a test with the fall apparatus. In the meantime, the gun is made ready and the contact targets put in place. The strips on which the "check records" are made are removed, and clean strips spun into the drum. The instruments may then continue to run *ad libitum* until the shot is fired. The motor switch button is then turned off, the strip with the velocity record removed and a new one inserted. (All strips are marked beforehand for proper identification). With the direct reading velocity scale, the velocity is read directly from the strip, and entered in the record book. The proper correc-

A comparison of the two types of chronographs, Boulengé and Aberdeen, brings out clearly the fact that the former is distinctly a laboratory instrument, requiring a very stable foundation at a minimum distance of several hundred yards from the gun platform, while the latter is a field instrument, which may be and is being used immediately behind the gun platform; or it may be set upon the ground as near the gun as may seem desirable. Proximity to the gun does not affect the records. The facts previously mentioned with reference to the two types of instruments may already have suggested that, while it takes

*By "reduction to muzzle" is meant the process of transforming the observed velocity to that which obtained at the muzzle, on the assumption that the projectile experienced uniform retardation from the instant it left the gun.

skilled operators, who are thoroughly familiar with the sources of error in the Boulengé and how to avoid them, to get acceptable results, the Aberdeen chronograph has from the outset been successfully used by operators who had had no previous training; they were enlisted men, taken from the ranks.

Many competitive tests as to accuracy were made during the process of development, measuring the velocity of the same projectile with a set of three Boulengé and a set of three Aberdeen chronographs. Average dispersions* for twenty rounds were computed for many series of firings. Invariably the average dispersion with the Boulengé chronograph was from two to four times as great as with the Aberdeen. In routine firings, the three Aberdeen chronographs agreed within one or two feet per second on a velocity of 1700 feet per second, and only rarely did the maximum dispersion at this value become as great as 5 feet per second.

One source of gratification is the fact that in spite of the "momentum of custom"—a phrase borrowed from a recent article upon the subject—the Aberdeen chronograph was one of the few devices developed under the pressure of necessity, which was fortunate enough to find a place in actual service of the government, and to play an important part in increasing the efficiency of the immense program of preparation which was so well under way when the armistice put an end to the hostilities.

*By dispersion is meant the maximum difference between any two of the three instruments used. The average dispersion is the sum of the dispersions divided by the number of rounds.

INVESTIGATION OF CHILLED IRON CAR WHEELS

For over half a century, the majority of the freight cars in use in the United States have been carried by chilled cast iron wheels. These wheels have given general satisfaction even under the greatly increased stresses due to the heavy rolling stock now in use. It has been noted for several years, however, that failures of freight car wheels occur quite frequently at the foot of long and steep grades. The cause of such failure appears to be the heating of the wheel produced by the prolonged application of the brakeshoes, this rise in temperature causing complicated stresses in the structure of the wheel. The stresses thus produced may be sufficient to cause cracking and failure and in all probability a derailment of the car under which the wheel is placed.

In order to determine the exact temperatures in different portions of the wheel, after prolonged heating of the rim, the Bureau of Standards has instituted a complete investigation of this subject. It is obvious that temperature measurements cannot readily be made upon a wheel in service and considerable ingenuity has been shown in perfecting a laboratory apparatus capable of producing conditions analogous to those met with on the road. The wheel is mounted in a vertical position and surrounded by electrical resistance coils insulated from but setting close against the rim of the wheel. Holes are drilled at all points at which it is desired to obtain temperature measurements and into these openings thermocouples are inserted. It is possible by regulating the flow of current through the resistor to raise the temperature of the rim to any desired amount, and the corresponding temperatures at other points may then be read. Quite a number of wheels have already been tested and others are being submitted from time to time by parties interested in the work.—*Technical News Bulletin*, Bureau of Standards.

WATER POWER BILL PASSED BY SENATE

January 15th the Senate passed the Water Power Development bill which is generally similar to the measure passed by the House last July, but contains some points of difference. The bill has been sent to conference for adjustment of House and Senate differences.

The bill as passed by the Senate provides for creation of a Federal Water Power Commission, composed of the Secretaries of War, Interior and Agriculture, which would be authorized after investigation, to issue licenses for development of water-power projects. The licenses would run for fifty years.

The measure further provides that the Federal commission shall co-operate with the States and other Federal agencies, that there shall be no charge on State and municipal power projects, and that industrial plants developing less than 200 h.p. shall not be required to pay a license. On two years' notice in writing the United States would have the right, at the expiration of a license, to take over and operate plants.

Power plants now in operation would not come under provision of the bill.

THE EXPRESSION OF DIELETRIC LOSSES IN CABLES

Correction

The following correction should be made on page 56 of the January JOURNAL.

The formula for "A" should be revised as follows:

$$\text{where } A = \log_{10}\left[\frac{d\sqrt{3}}{a} \quad \frac{b^2 - d^2}{\sqrt{b^4 + b^2\ d^2 + d^4}}\right]$$

Three lines below should be changed to read as follows:

$d = 1/\sqrt{3}$ of distance between centers of conductors.

Notes on the Synchronous Commutator

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AND

T. ISSHIKI

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In the use of the synchronous commutator in series connection as a suppressor, serious errors may arise due to relatively small amounts of capacity in the commutator and galvanometer circuits. The magnitude of these errors is studied for a number of different connections, and methods for eliminating them are pointed out. A number of wave forms are given, indicating the nature of the errors.

Used as a shunt suppressor the commutator is far more reliable and this method of connection is always to be preferred.

An appendix gives a theoretical analysis of two cases investigated and shows a close agreement with the experimental observations.

In certain methods of measurement of the crest values of high alternating voltages it is necessary to measure accurately the average values of very small alternating currents. One of the commonest of these methods is that in which a condenser, in series with a low resistance, is placed across the voltage and the voltage drop over the resistance, due to the charging current, measured on an instrument of D'Arsonval type with high series resistance, through the use of either a synchronous commutator or rectifying vacuum tubes.

In these methods, if the commutator is used the instrument receives either a rectified alternating current, made up of both half waves, or a uni-directional pulsating current, made up of alternate half waves with the intermediate opposite half waves cut out either by opening the circuit (series commutator), or by short-circuiting the instrument (shunt commutator). When the commutator is used so as to eliminate alternate half waves, F. Bedell[1] has called it a *suppressor*. If the rectifying vacuum tube is used the current in the measuring instrument is always pulsating with alternate half waves cut out. In any of the above mentioned cases the instrument reads the average current in terms of its calibration by continuous current. For the cases in which the current is pulsating, the instrument reading is multiplied by two to obtain the average value of the condenser charging current, it being assumed that the active half wave of charging current is accurately reproduced in the instrument and that in the intervening half wave interruption no current flows in the instrument.[2]

Measurements of crest value by these methods are probably the best so far obtained, but apparently no special effort has been made to put them on a precision basis. When a sensitive galvanometer is used, the pulsating character of the current raises questions as to the influence of capacitance and reactance in the instrument circuit, and as to the validity of the factor 2 mentioned above. The observations recorded below show that under certain circuit conditions serious errors may arise.

The Apparatus

The commutator used in the experiments was six inches in diameter and had six brass segments ½-in. wide, insulated from each other by 1/32-in. built-up mica, and from the hub by standard V-shaped commutator bushings. Two brass rings, 6-in. in diameter and ½-in. wide, were mounted one on each side of the central commutator segments and insulated from them by intermediate bakelite rings. Screws holding the outer brass rings in place, passed through the bakelite connecting the outside continuous rings to opposite sets of three alternate commutator segments. The commutator was mounted on the end of the shaft of the 6-pole generator. Four brushes of 1/64-in. thick spring bronze, stiffened with backings of steel spring, were carried on a graduated bakelite disc arranged for complete rotation about the axis and clamping in any position. The commutator was machine-constructed throughout. It was frequently tested for insulation and showed throughout a resistance of the order 10^3 megohms.

The 6-pole generator was single phase and had a capacity of 5 kw. at 60 cycles and 120 volts. It was driven by an adjustable-speed continuous-current shunt motor, permitting a range of frequency from 20 to 90 cycles. The armature was surface wound, giving a smooth wave approximating closely to sine shape.

Two D'Arsonval galvanometers were used, both of suspension type, read by telescope and scale. One, No. 24515, had a resistance of 115 ohms, a sensitivity of 40 megohms, an undamped period of 9.5 seconds, and a critical damping resistance of 560 ohms. The corresponding figures for the other galvanometer, No. 23518, were 1680 ohms, 1280 megohms, 22 seconds, and 3400 ohms. The sensitivities for the two instruments when critically damped therefore were 33 and 420 megohms, respectively.

To be presented at the 8th Midwinter Convention of the A. I. E. E., New York, February 20, 1920.

1. F. Bedell, *Journal of Franklin Institute*, No. 176, 1913, p. 385.

2. W. E. Sumpner, *Philosophical Magazine*, p. 155, January 1905.

Commutator as Series Suppressor

Obviously the most rigid test of the circuit and instrument for pulsating current is to apply a continuous electromotive force, chopping it up into alternate intervals at full value and zero value by means of the series commutator, as indicated in full lines in Fig. 1. The complete interruption of the current and the sudden application of the full electromotive force accentuate any conditions tending to upset the perfect rectangular half wave alternating with a half period of complete interruption. The test of this performance is the ratio of the readings of the galvanometer with commutator at standstill and when running. This ratio should be 2. This arrangement uses only two brushes and will be spoken of as the series connection of the commutator.

Fig. 1 shows the commutator in series connection; that is, as a simple make and break device in the circuit containing a single dry cell E, resistance $R = 10^6$ ohms and $r = 10^4$ ohms and the galvanometer shunted with its critical damping resistance. Several different types of resistance were used for R; a series of carbon lightning arrester rods aggregating 200,000 ohms, a series

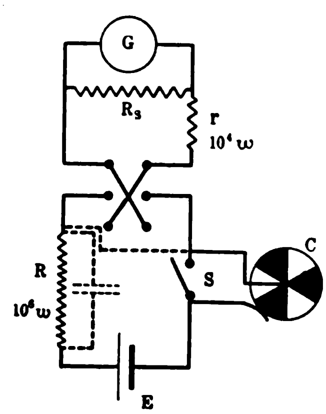

Fig. 1—Commutator Connected as Series Suppressor

of so-called "lavite" units aggregating 10^6 ohms, and a precision set of non-inductive, capacity-free, manganin units aggregating 10^6 ohms, in which the wire was wound in single layers on thin micanite plates, suspended on glass rods.

A number of observations were made at different speeds of the commutator C, and with S open and closed, corresponding to running and standstill conditions for C. In every case it was found that the ratio of galvanometer deflections for running and standstill was greater than 0.5. A typical set of observations is shown in Table I and plotted in Fig. 2 as curve No. 2. The speed, in terms of the frequency of the generator, is plotted as abscissa, and the ratio of running to standstill deflection of the galvanometer as ordinate.

The increase of the ratio of running to standstill deflections with the frequency obviously suggests the presence of capacity as a disturbing element. This was confirmed by a rearrangement of the apparatus and connections so as to reduce the capacity in circuit. In Fig. 2, curve No. 1, the resistance R was connected into the circuit over a pair of leads consisting of twisted lamp cord about 100-ft. long and having a capacity of about 0.005 microfarads. In curve No. 2, R^1 was a small compact resistance of the same

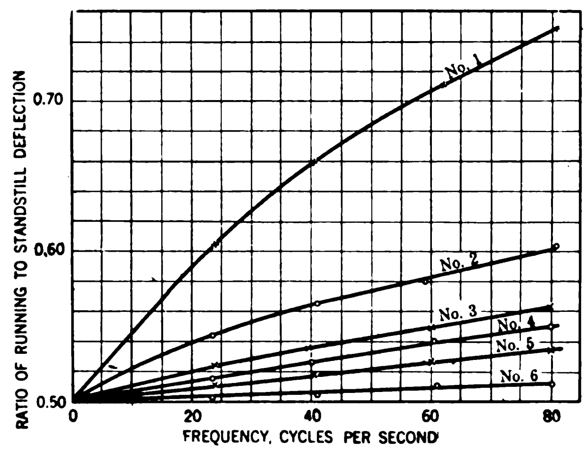

Fig. 2—Ratio of Running to Standstill Deflection for Various Speeds of Commutator. Commutator in Series

No. 1—Leads for 10^6 ohm Resistance: 100 ft. Twisted Lamp Cord (Capacity about .005 microfarads), Leads for Commutator: 15 ft. Twisted Lamp Cord (Capacity about .0007 microfarads), Brush Narrower than Insulation between Segments.
No. 2—Leads for 10 ohm Resistance: Short Separated Wires, Leads for Commutator: Same as No. 1. Brush Wider than Insulation between Segments.
No. 3—Same as No. 1 except that Leads for 10^6 ohm Resistance Were Separated to Two 100 ft. Wires.
No. 4—Same as No. 2 except that Brush was narrower than Insulation between Segments.
No. 5—Same as No. 3 except that Commutator Leads Were also separated.
No. 6—Same as No. 4 except that Commutator Leads Were Separated

TABLE I

Speed cycles	Deflection of galvanometer						
	Running			Standstill			Running / Standstill
	left	right	mean	left	right	mean	
23.5	5.6	5.59	5.595	10.22	10.32	10.27	0.545
41	5.8	5.80	5.80	10.22	10.32	10.27	0.565
59	5.95	5.95	5.95	10.22	10.32	10.27	0.580
81	6.2	6.18	6.19	10.22	10.32	10.27	0.603

value as that pertaining to curve No. 1, but connected to the circuit with short leads. The remaining curves showing decreasing departure of the ratio of running to standstill values from 0.5, show the successive improvements resulting from shortening and separating the various connections of Fig. 1. It should be noticed, however, that under the very best conditions

of short, well-separated connections, with the arrangement of Fig. 1, there is always an error in assuming a ratio of running to standstill deflections of 0.5 and this error increases with the frequency.

By means of the method of connection shown in Fig. 3, it was found that in the half wave in which the circuit is closed by C, the current is greater than the standstill value, and during the half wave in which the circuit is opened by C there is still some current in the positive direction. B is a second com-

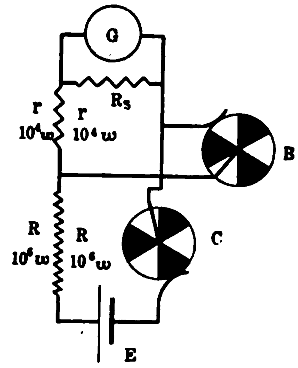

Fig. 3—Series and Shunt Suppressors in the Same Circuits

mutator on the same shaft with C and is connected in shunt with the galvanometer, as indicated. By proper setting of the brushes of B it is a simple matter to short-circuit the galvanometer for the periods of opening or closing by C, and thus read the current for the opposite half wave. For example, at standstill, with B open and C closed, the galvanometer reading was 9.9; when running and with B set for reading during closed C and open C, respectively, the readings were as follows:

TABLE II

Speed cycles	Closed C	Open C
23	5.78	1.1
41	6.15	1.38
60	6.5	1.7
77	6.7	....
80	....	1.9

Since in each case the galvanometer is receiving current only one-half the time, the readings must be multiplied by 2 to obtain the full values. They show therefore that during the half wave of closed C the current is greater than 9.9, and during the half wave of open C the current is greater than 0. Moreover the excess of current value increases with the frequency.

A further study of the influence of capacity with the connection of Fig. 1 was made by inserting additional capacity in shunt to the resistance R, between the commutator leads, and between commutator segments. In the upper part of Fig. 4 curves are plotted showing the variation of the ratio of running to standstill deflection with the frequency for series commutator and for different values of capacity connected in shunt to the resistance R. The lower half of Fig. 4 gives curves taken with the commutator in shunt connection. These curves will be referred to below. Similar curves are obtained when the capacity is connected between the leads to the commutator.

In Fig. 5 the two lower curves were taken at 60 cycles with various values of capacity connected be-

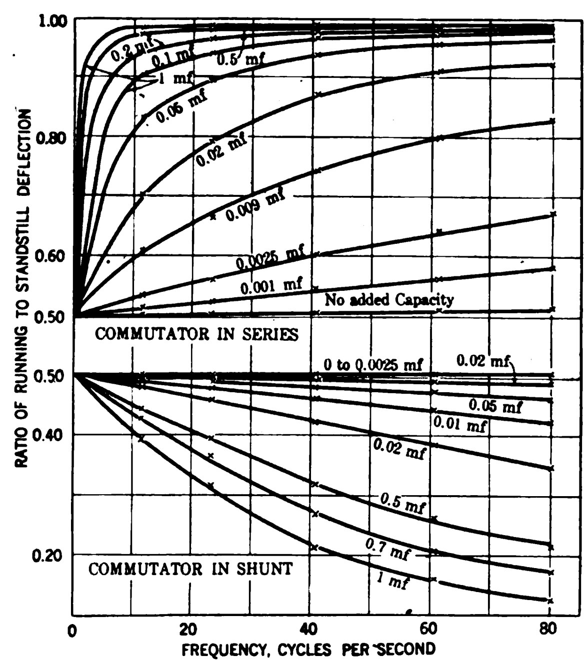

Fig. 4—Influence of Capacity in Shunt to 10⁶ Ohm Resistance upon Ratio of Running to Standstill Deflection. Brush Narrower than Insulation between Segments

tween the opposite sets of segments of the commutator. This connection is made by connecting the capacity in parallel with the two outer collector rings of the commutator. Curve No. 2 is taken with a brush which is thicker than the insulation between segments and curve No. 3 is taken with a brush which is thinner than the insulation between segments. It is noteworthy that the use of the thick brush, short-circuiting as it does the capacity shunted around the commutator and thus discharging the capacity, is the cause of a wide error in the value of the ratio of running to standstill deflections. Curve No. 1 shows that the effect of adding capacity between commutator leads is similar to that of adding capacity between the terminals of R.

In view of the foregoing results, it appeared of interest to study the wave form of the current in the galvanometer. The current values being too small for the oscillograph, the method shown in Fig. 6 was adopted. C is the rectifying commutator already described arranged for series connection, that is, using only two brushes and operating as a half cycle make and break. Switching is also provided so that C may be arranged in shunt connection or cut out entirely. D is a metal disc also mounted on the generator shaft and equipped with three narrow insulating sectors set in its outer surface. Two brushes on D short-circuit the galvanometer, as indicated, during a complete cycle except for the brief interval when the short circuit is interrupted by one of the insulating segments, that is, once in each cycle of make and break. The particular instant in the cycle at which the galvanometer receives current is varied by rotating the brushes on C. The arrangement constitutes a point by point method for studying the current in the circuit of the commutator C.

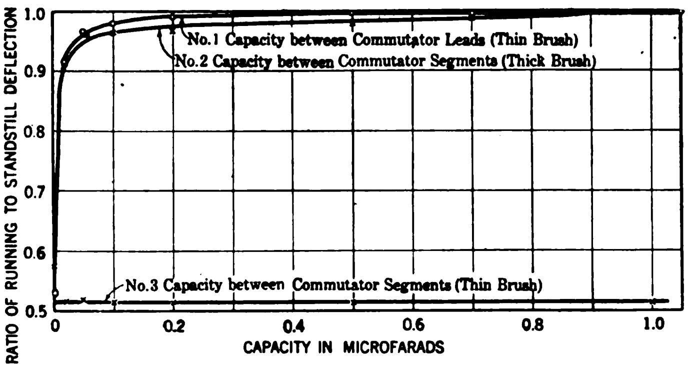

Fig. 5—Influence of Capacity between Commutator Leads and between Commutator Segments upon Ratio of Running to Standstill Deflection. Commutator in Series. 60 Cycles

Observations were taken with C both in series and in shunt. A typical set is given in Table 3 and plotted in Fig. 7. It was found that with D operating and C cut out completely, that is, with steady current in the battery circuit, the deflection of the galvanometer had a slow and irregular variation and usually different values for opposite positions of the reversing switch. These variations were due to thermal electromotive forces or other variable contact conditions at the brushes of D. In order to eliminate this trouble right and left readings of the steady current (C not in circuit) and of the instantaneous current (C in circuit) were taken in quick succession and their mean values used. The wave form is obtained by taking for each brush setting the ratio of the mean of the instantaneous readings to the mean of the steady readings.

The more interesting results are plotted in the curves of Figs. 7, 8 and 9, showing several forms for both series and shunt connections of the commutator. In the case of Fig. 7 the frequency was 60 cycles and the 1-megohm resistance R and the commutator C had leads consisting of twisted lamp cord 100-ft. and 15-ft. long (capacities about 0.005 and 0.0007 microfarads) respectively, the brush was thinner than the width of the insulating segments in the commutator C. In Fig. 8 the conditions were the same at a frequency 24 cycles, and in the lower curve a brush thicker than the insulating commutator segments was used. In Fig. 9 short separated leads of minimum capacity were used to R, and the 15-ft. twisted leads to C.

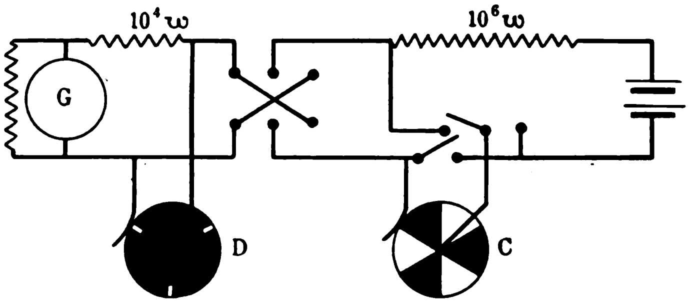

Fig. 6—Connections for Taking Wave Forms of Series and Shunt Suppressors

As already indicated, the results shown in the foregoing figures are due to the capacity located in different parts of the connections. For example, in Fig. 7, during open circuit by the commutator, the capacity of the commutator itself charges as indicated at (a) and C' the capacity around the resistance R discharges

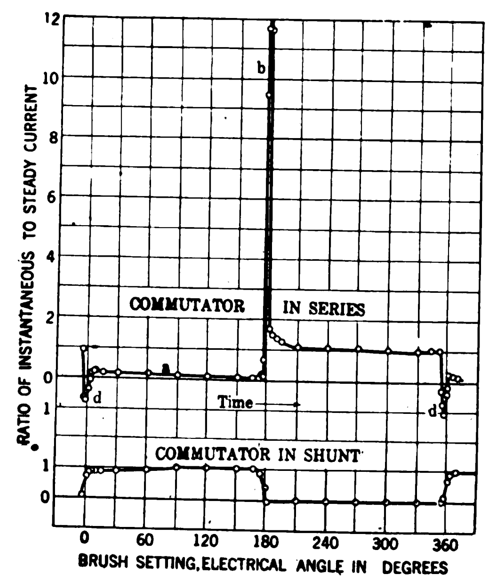

Fig. 7—Wave Form of Current Through Galvanometer. 60 Cycles. Brush Narrower than Insulation between Segments. Leads for 10^6 Ohm Resistance: 100 ft. Twisted Lamp Cord (Capacity about .005 Microfarads. Leads for Commutator: 15 ft. Twisted Lamp Cord (Capacity about .0007 Microfarads)

TABLE III

60 cycles, brush narrower than insulation between commutator segments, leads for 10^6 ohms resistance, twisted lamp cord 100 ft. long, (capacity about .005 microfarads), leads for commutator—twisted lamp cord 15 ft. long, (capacity about .0007 microfarads)

Electrical Angle degree	Commutator in Series							Commutator in Shunt						
	Deflection for instantaneous current (C in circuit)			Deflection for steady current (C not in circuit)			Ratio: inst. / st'dy	Deflection for instantaneous current (C in circuit)			Deflection for steady current (C not in circuit)			Ratio: inst. / steady
	left	right	mean	left	right	mean		left	right	mean	left	right	mean	
-6	1.7	1	1.35				.97							
-3	-.6	-1.4	-1	1.80	1.00	1.40	-.72	.28	- .1	.09	1.22	.98	1.10	.08
-1.5	-.62	-1.88	-1.25	2.08	1.12	1.60	-.78							
0	.20	-.15	-.65				-.41	.88	.72	.80				.73
1.5	.5	-.88	-.19				-.12							
3	.9	-.47	.215				.14	.95	1.00	.975				.89
6	.85	-.32	.265	2.08	1.12	1.60	.17	.95	1.00	.975				.89
9	.92	-.30	.31				.19	.95	1.00	.975				.89
15	.63	-.02	.305				.19	.95	.92	.935				.85
30	.60	-.08	.26				.16	1.02	.92	.970				.89
60	.57	-.17	.2				.12	1.02	.92	.970	1.20	.99	1.095	.89
90	.48	-.22	.13				.08	1.10	1.00	1.05	1.12	.92	1.02	1.03
120	.57	-.32	.125	2.18	1.12	1.65	.08	1.10	1.00	1.05				1.03
150	.7	-.42	.14				.09	1.10	1.00	1.05				1.03
165	.7	-.47	.115				.07	1.10	1.00	1.05				1.03
171	.72	-.47	.125				.08							
174	.78	-.45	.165	2.18	1.12	1.65	.10	1.08	.92	1.00				.98
175.5	.97	1.09	1.03				.62							
177	16.2	15.6	15.9	2.22	1.12	1.67	9.52	.62	.21	.42	1.12	.92	1.02	.41
178.5	19.0	18.6	18.8				11.70							
180	18.6	17.5	18.05				11.63	.18	-.20	-.01				.01
181.5	2.9	2.0	2.45				1.63							
183	2.68	1.82	2.25				1.52							
186	2.42	1.55	1.99	1.78	1.05	1.415	1.40							
195	1.42	2.2	1.81				1.25							

through the resistance. At (*b*) on the instant of closing, the capacity C' charges, giving an excess current through the galvanometer which immediately tends to fall to the value fixed by the resistance R.

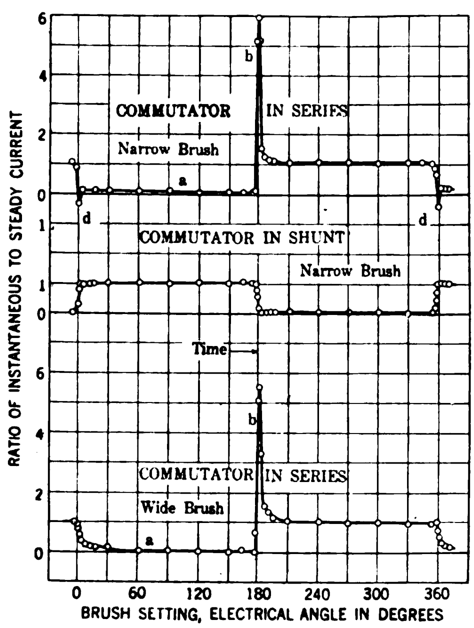

FIG. 8—WAVE FORM OF CURRENT THROUGH GALVANOMETER. 24 CYCLES. ALL LEADS SAME AS FIG. 7

At (*d*) if the brush is narrower than the insulating segment of the commutator, the counter-electromotive forces of the capacities C and C' are in series and therefore greater than the battery electromotive force E; hence, there is momentarily a reverse current after the circuit opens. Then as C' discharges through R the electromotive force falls and the battery charges the capacity of the commutator, resulting in a positive charging current for the interval (a). If the brush on C is wider than the insulating segment, the capacity of C is discharged through the brush and during the following interval of open circuit the charging current of this capacity is higher. (See Fig. 8, lower curve).

When the leads to the commutator contain capacity with either a wide or narrow brush, the capacity discharges through the commutator and not through the galvanometer at each interval of make, and therefore this capacity charges through the galvanometer during each interval of break; hence there is excess current through the galvanometer at each interval of break, resulting in an increase of the ratio of running to standstill conditions. (See curves of Figs. 5, 7, 8, 9).

The effect of capacity between segments in the commutator itself is as follows: This capacity charges during open circuit. If a thick commutator brush is

used, the capacity discharges through the brush at the instant the brush bridges the insulating commutator segment, and hence the capacity charges in each interval of open circuit, giving excess galvanometer current and increased ratio of running to standstill current. If, on the other hand, the commutator brush is narrower than the insulating segment, the capacity retains its charge except for loss due to leakage and hence there is no recharge and no excess galvanometer current after the first charging interval, consequently the ratio of running to standstill current in the galvanometer is independent of the value of the capacity and approximately equal to 0.5. (See curves of Fig. 5).

The apparent errors of the series connected com-

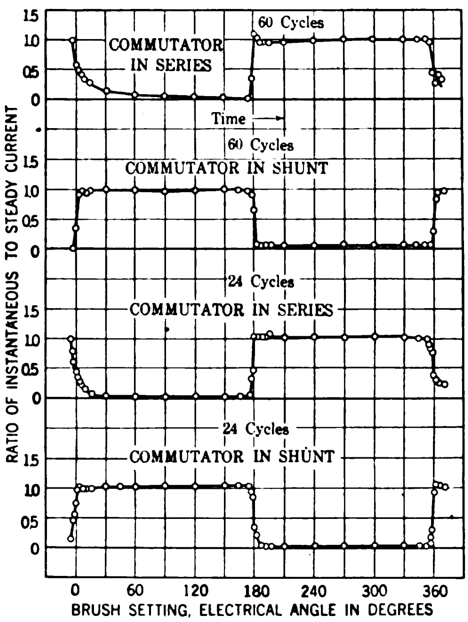

Fig. 9—Wave Form of Current through Galvanometer, Brush Narrower than Insulation between Segments. Leads for 10^6 Ohm Resistance: Short Separated Wires. Leads for Commutator: 15 ft. Twisted Lamp Cord (Capacity about 0.0007 Microfarads)

mutator may be reduced to a minimum or avoided entirely in two ways: First, by any method of connection whereby the current in the resistance R is not interrupted. Two methods of accomplishing this are shown in Figs. 10 and 11. In Fig. 10, by using three brushes on the commutator during the period in which the galvanometer current is interrupted, the current in R is maintained at constant value by means of the resistance R' of value equal to that in the galvanometer circuit. A number of accurate observations with this method of connection at various values of frequency and capacity were made, and the ratio of running to standstill deflection of the galvanometer was very accurately 0.5 throughout, except for the case of large capacity connected between the points (b) and (c). In Fig. 11 the current in R is also constant and the galvanometer may be shunted around either of the resistances r. In a series of experiments with this connection, 120-volts continuous potential was used, and capacity up to 1 microfarad was shunted around both resistances R and r, in order to intensify any disturbances due to charging currents. Both at 24 cycles and 60 cycles the ratio of running to standstill deflection was accurately equal to 0.5 throughout.

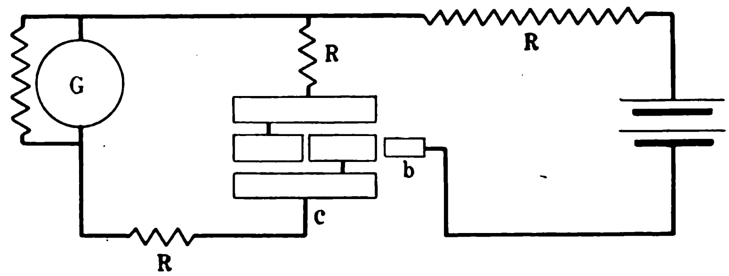

Fig. 10—Connections of Series Suppressor for Eliminating Errors Due to Capacity

A second method for reducing the error in the simple connection of Fig. 1 is a reduction of the value of the resistance R. Using the twisted lamp cord leads mentioned above, to R and C, Fig. 12 shows a series of observations at 60 cycles on the value of the ratio of running to standstill deflections in relation to the value of R. As indicated, when R is equal to 1 megohm the ratio is 0.72 and the current in circuit is 3.1×10^{-6}

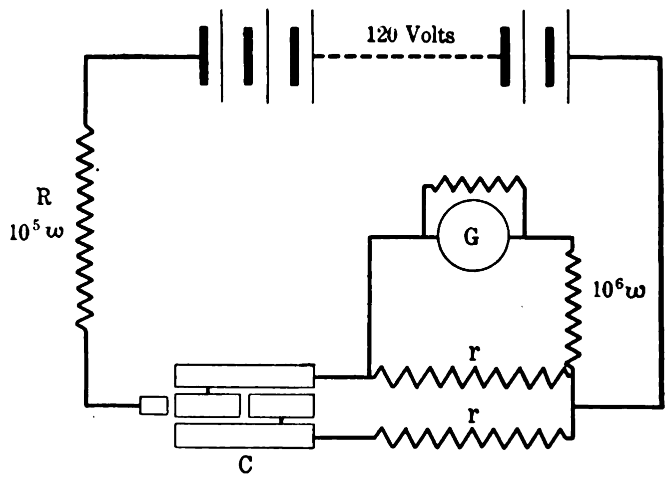

Fig. 11—Connections of Series Suppressor for Eliminating Errors Due to Capacity

amperes. For $R = 5 \times 10^{-4}$ ohms the ratio is 0.51 and the current 6.2×10^{-5} amperes. For $R = 10^4$ and 10^3 ohms, the ratios were found to be 0.501 and 0.4995 respectively. In the last case the current in circuit was approximately 3.1 milliamperes. (See Fig. 12).

Analyses of the series commutator connection for capacity C, shunted around the resistance R and across the commutator leads, are given in an appendix. It is shown that the value of the ratio of instan-

taneous to steady current in the galvanometer for any particular position of the brush setting, as well as the ratio of running to standstill deflections of the galvanometer, are functions only of the product $f\ C\ R$ and of α where f is the frequency and α is the ratio of R to r (see Fig. 1). That is, reductions in the values of frequency, capacity or of the resistance R, all result in a closer approach of the ratio of running to standstill deflections to the value 0.5. Curves are also given showing a close agreement between the observations and the theory.

Commutator Connected as Shunt Suppressor

With the commutator connected in shunt, as indicated by the dotted line in Fig. 1, the errors due to capacity are not so serious as in the series connection. In the shunt connection, since the current through R varies only by the alternate cutting in and out of the relatively small resistance of the galvanometer circuit, the variation of electromotive force at its terminals is correspondingly small. Throughout a number of observations with this method of connection the ratio of running to standstill deflections was very accurately 0.5 even when the ratio R/r was not greater than 10 (values at 23, 40, 60 and 80 cycles all being 0.501). Although the current pulsation in R in this case is relatively great, the low value of R tends to reduce the charging current of any small capacity which may exist. For values of the ratio R/r greater than 100, the current pulsation is small and if the circuit has no capacity, the error is small (values of ratio R/r at the above frequencies being 0.502, 0.501, 0.501 and 0.500).

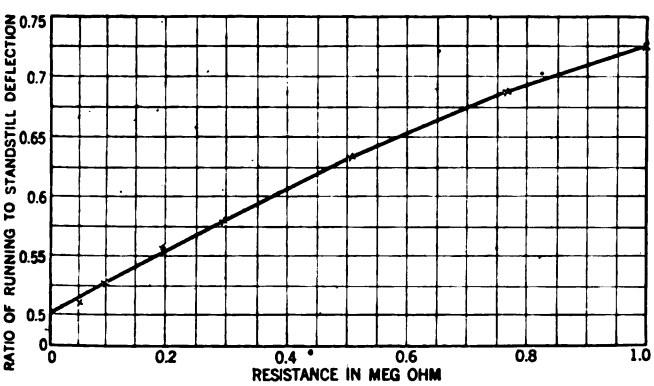

Fig. 12—Effect of Variation of R in Fig. 1 upon Ratio of Running to Standstill Deflections. Commutator in Series. 60 Cycles. Thin Brush

Capacity, however, soon introduces trouble. When located in the leads to the commutator it charges on open commutator and discharges on a closed commutator. Thus during the open period current is shunted from the galvanometer, lowering the ratio of running to standstill deflections. The phenomenon is the same for thin and thick commutator brushes. In a series of observations at 24 cycles, the ratio decreased from 0.504 to 0.298 in increasing the capacity between the leads from 0 to 1 microfarad.

When there is any capacity between the commutator segments, this capacity charges and stays charged without influence on the ratio of running to stand at standstill deflections if the commutator brush is thinner than the insulation between segments. With a thick brush, however, the capacity discharges when the brush bridges the insulating segment and then charges in the position of open commutator, the performance then being as in the case of the foregoing paragraph. The capacity between commutator segments, as measured, was found to be 0.00126 microfarad. In a series of observations the addition of 0.02 microfarad between commutator segments changes the ratio of running to standstill values from 0.498 to 0.488 with still further lowering for increase of capacity.

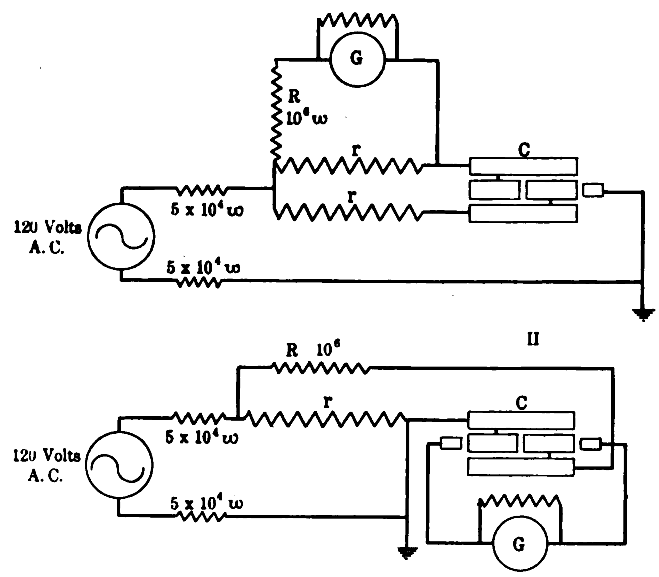

Fig. 13—Series Commutator. Elimination of Electrostatic Unbalancing

When there is capacity in the leads to R on closed commutator, this capacity receives the full battery e.m.f. On open commutator at the instant of opening, the counter e.m.f. of the capacity is equal to that of the battery and no current flows in the galvanometer G. As the capacity discharges through R there is a delay in the rise of current to its full value, thus causing a lowering of the ratio of running to standstill deflections, and in greater amount the greater the capacity shunting R. (See Fig. 7, and curves in the lower half of Fig. 4).

Performance on Alternating Current

The errors arising from the presence of capacity in using the commutator with alternating current are smaller than those that have been described. This is to be expected since on commutation the alternating

TABLE IV

r ohm	Deflection of Galvanometer						
	Full Wave (Fig. 13, I)			Half Wave (Fig. 13, II)			Half wave / Full wave
	left	right	mean	left	right	mean	
1000	3.63	3.69	3.66	1.83	1.83	1.83	0.500
1000*	3.66	3.70	3.68	1.83	1.83	1.83	0.497
2000	7.30	7.38	7.34	3.63	3.68	3.655	0.499
2000*	7.30	7.32	7.31	3.63	3.63	3.63	0.497

current tends to rise gradually from the zero value and not abruptly as in the case of the pulsating continuous current. In a number of observations taken with alternating current introduced by means of a transformer located in place of the battery of Fig. 1 and with the commutator connected in both series and shunt for reading alternate half waves and also for the reading of full rectification by means of the addition of two more brushes to the commutator in the usual manner, the ratios were found to be very accurately 0.5 under *properly selected* conditions. However, even with careful elimination of capacity from all connections considerable errors may be introduced by reason of unsymmetrical electro-static relation of the various parts of the circuit. For example, introducing alternating e.m.f. in place of the battery in Fig. 11 for obtaining alternate half waves in the galvanometer, and then by a simple change of connections sending the complete rectified alternating

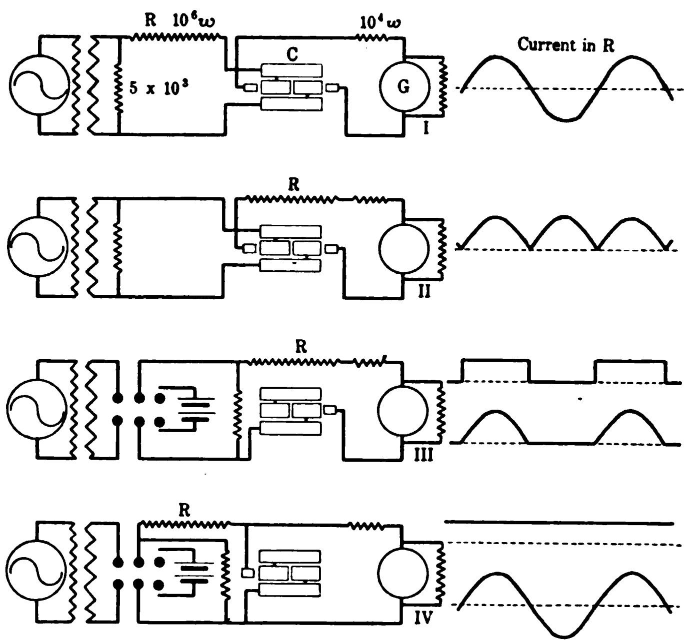

FIG. 14—SERIES AND SHUNT COMMUTATORS. COMPARISON OF VARIOUS TYPES OF PULSATING CURRENT IN SERIES RESISTANCE

current through *G*, the ratio of half wave to full wave deflections was found to be 0.511. When, however, the circuit was rearranged, as shown in Fig. 13, so as

TABLE V

Electrical angle degree	Deflection of Galvanometer											
	Connection I			Connection II			Connection III			Connection IV		
	left	right	mean	left	right	mean	left	right	mean	left	right	mean
-3	-.2	-.1	-.15	-.32	-3.	-.31	-.25	-.25	-.25	-.1	-.02	-.06
0	.32	.5	.41	.22	.28	.25	.02	.02	.02	.22	.28	.25
3	.88	1.1	.99	.78	.8	.79	.31	.31	.31	.48	.52	.5
9	1.99	2.1	2.05	1.8	1.85	1.83	.8	.82	.81	.98	1.08	1.03
15	3.0	3.12	3.06	2.88	2.9	2.89	1.32	1.38	1.35	1.5	1.6	1.55
30	5.37	5.5	5.44	5.21	5.28	5.25	2.5	2.58	2.54	2.7	2.78	2.74
45	7.37	7.52	7.45	7.22	7.32	7.27	3.51	3.59	3.55	3.67	3.78	3.73
60	8.8	9.1	8.95	8.8	8.9	8.35	4.31	4.39	4.35	4.4	4.5	4.45
75	9.7	9.98	9.84	9.69	9.81	9.75	4.8	4.88	4.84	4.88	5.00	4.89
81	9.9	10.08	9.99	9.82	10.0	9.91	4.9	4.95	4.93	4.92	5.1	5.01
87	9.98	10.1	10.04	9.92	10.07	10.0	4.95	5	4.98	4.95	5.1	5.03
90	9.98	10.1	10.04	9.95	10.05	10.0	4.97	5.01	4.99	4.95	5.1	5.03
93	9.95	10.07	10.01	9.9	10.07	10.04	4.93	5.	4.97	4.91	5.1	5.01
105	9.6	9.75	9.68	9.6	9.72	9.66	4.8	4.88	4.84	4.75	4.9	4.83
120	8.62	8.68	8.65	8.62	8.72	8.67	4.32	4.4	4.36	4.2	4.4	4.3
135	7.02	7.02	7.02	7.07	7.15	7.11	3.58	3.62	3.6	3.4	3.58	3.49
150	4.88	4.85	4.87	4.98	5.05	5.02	2.53	2.6	2.57	2.32	2.5	2.41
165	2.38	2.38	2.38	2.5	2.62	2.56	1.32	1.38	1.35	1.22	1.1	1.16
177	.28	.2	2.4	.38	.43	.41	2.7	.32	.30	.08	.18	.13
180	-.2	-.2	-.2	-.08	0	-.04	.09	.1	.10	-.2	-.09	-.15
183	-.8	-.97	-.89	-.7	-.68	-.69	-.3	-.2	-.25	-.5	-.4	-.45

to divide the resistance R between the two halves of the circuit, the results of Table IV are obtained, showing that the ratio for half wave to full wave deflection of the galvanometer is very close to 0.5. In these circumstances capacity (up to one microfarad) may be shunted to r or R without affecting the ratio 0.5 of half wave to full wave. The position of the brushes was usually set for maximum deflection, although the method of setting for zero deflection and then shifting 90 electrical degrees was sometimes used.

For further study of the influence of capacity, the connections shown in Fig. 14 were used. Connection *I* gives complete rectification and normal alternating current through the resistance R. Connection *II* gives complete rectification with pulsating current through R. Connection *III* is the simple series connection for both R and the galvanometer and therefore has pulsating current in R with alternate half waves eliminated. Connection *IV* is ordinary shunt connection with normal alternating current in R. In all cases current is introduced into the circuit through a step-down transformer giving very low voltage in the galvanometer circuit.

Table V gives the readings taken with each of the methods of connections shown in Fig. 14, for various positions of the commutator brushes. The results are plotted in Fig. 15. It is of interest to note that in this case in which capacity has been eliminated as far as possible, the ratio of the half wave to the full wave deflection is very closely equal to 0.5 for all positions of brushes, independent of the method of connection.

Fig. 16 shows the effect of shunting the resistance R with 0.02 microfarad. In this case the ratio of the maximum value for connection *IV* to the maximum

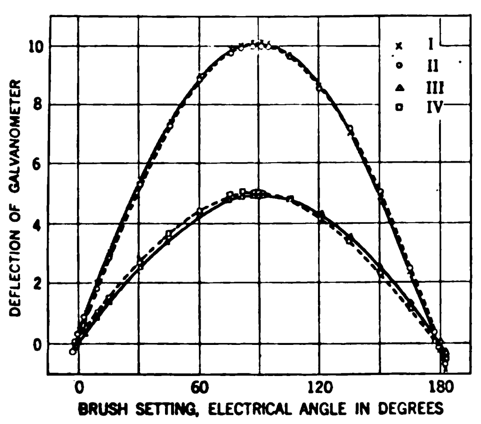

FIG. 15—DEFLECTION OF GALVANOMETER FOR VARIOUS POSITIONS OF BRUSHES, CONNECTION FIG. 14. CAPACITY ELIMINATED AS FAR AS POSSIBLE

value for connection *I* is 0.498, thus indicating the reliability of the shunt method of connection. On the other hand, the ratio of the maximum value for connection *III* to the maximum value for connection *I* is only 0.105, showing the unreliability of the series commutator connection when the circuit contains any capacity.

In order to compare the disturbance introduced in the series connection by the presence of capacity when using continuous and alternating currents, observations were taken with very small values of capacity by making the connections to R with two lengths of

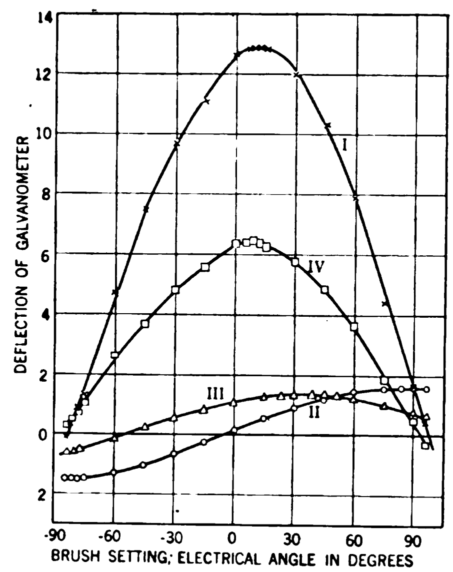

FIG. 16—DEFLECTION OF GALVANOMETER FOR VARIOUS POSITIONS OF BRUSHES, CONNECTION FIG. 14. RESISTANCE R SHUNTED BY 0.02 MICROFARAD CAPACITY

twisted lamp cord, introducing capacities of 0.002 and 0.006 microfarads respectively. The observations were taken at 60 cycles and the results are given in Table 6. The upper line gives the ratios of half wave to full wave for alternating current, as determined by connections *III* and *II*, respectively, and the lower line the ratio of running to standstill deflection using continuous current.

TABLE VI
INFLUENCE OF CAPACITY ON HALF WAVE READING

Capacity m.f.	0	0.002	0.006	0.02
A.C.	0.496	0.509	0.616	0.849
D.C.	0.51	0.602	0.741	0.907

It will be noticed, while that generally in the same direction, the disturbing effect of the capacity is less for alternating than for continuous current.

DISCUSSION

Small alternating currents may be measured by means of a synchronous commutator with a high sensitivity D'Arsonval galvanometer. The combination

may be placed directly in the circuit, or perferably may be used in conjunction with high non-inductive series resistance to measure the voltage drop over a relatively low non-inductive resistance carrying the current to be measured.

The commutator may be connected in series with the galvanometer so as to open and close its circuit during alternating half waves, in shunt so as to short-circuit the galvanometer during alternate half`waves, or it may be connected so as to completely rectify the alternating wave, thus making use of both half waves. In the two former methods of connection the commutator is spoken of as a suppressor.

In all methods of connection under steady conditions the galvanometer reads the average value of current passing through it in terms of its continuous current calibration. With either type of suppressor, since the instrument receives current during only one-half cycle, the value of the reading is multiplied by two in order to obtain the average value of the alternating current as based on the continuous current calibration.

Using the series suppressor, serious errors may arise due to relatively small values of capacity in the resistances and connections of the galvanometer and commutator circuit. Owing to the interruption of the circuit the capacity charges and discharges in such a way as to increase the instrument current during the closed half cycle and to raise it above zero value in the open half cycle. This source of error may be avoided if during the open half cycle the source of alternating current or electromotive force is kept closed by a second circuit equivalent to that of the galvanometer. This may be done by using the opposite segments of the commutator. (See Fig. 10).

The shunt suppressor is far more reliable and with careful elimination of capacity from the galvanometer circuit the errors may be reduced to negligible values.

If it is desired to use the series suppressor the circuit conditions may be tested by taking the ratio of the deflections due to the pulsating current, consisting of alternating half waves, and that due to the completely rectified alternating current by means of connections similar to those in Fig. 14. This ratio should be 0.5. This test should be followed by one applying a continuous e.m.f. with the commutator connected as either a series or a shunt suppressor. The test lies in the ratio of the running to standstill deflections of the galvanometer. This ratio should be 0.5. For the simple series suppressor the value will be always higher than 0.5 unless an auxiliary circuit is used. With the shunt suppressor the value 0.5 may be very closely reached.

In using rectifying vacuum tubes in place of a commutator, two tubes and two resistances must be placed in the alternating circuit. The voltage drop over either resistance may be used for measuring the current. In this case the e.m.f. applied to the galvanometer is the pulsating unidirectional e.m.f. due to alternate half waves. Since no commutator is used, the galvanometer circuit with its series resistance is closed at all times and the presence of capacity introduces no error.

Following is a summary of the conclusions from the tests:

(1) In the use of the synchronous commutator as a series suppressor, serious errors may arise due to relatively small amounts of capacity in the commutator and galvanometer circuits.

(2) Used as a shunt suppressor the commutator is far more reliable and this method of connection is always to be preferred.

(3) The galvanometer should be calibrated with continuous current with the commutator both at standstill and running as an ordinary make and break. If the ratio of these two readings is 2, the circuit cont ditions will introduce no error with alternating currenr.

(4) Several sources of error due to the commutato- are eliminated by the use of vacuum tube rectifiers.

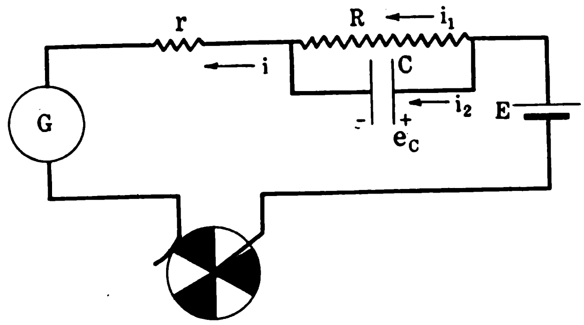

FIG. 17

(5) A number of wave forms of alternating current of very low value are given.

APPENDIX

The following mathematical analysis of the case of the series suppressor as described in the paper gives results in close agreement with those observed.

I. Series suppressor in which the high resistance R is shunted by capacity C and continuous electromotive force E applied. No other capacity in circuit.

Referring to Fig. 17, let i, i_1 and i_2 be the instantaneous currents through galvanometer, R, and C (charging current) respectively, and e_c the instantaneous value of the voltage over C, and let their positive directions be those shown by arrows.

Consider the interval (half cycle) during which the circuit is closed by the commutator. Let us call this interval "closed half cycle". During this half cycle C is charged.

We have

$$i r + i_1 R = E \tag{1}$$

$$i_1 R = e_c = 1/C \int i_2 \, dt \tag{2}$$

$$i_1 + i_2 = i \tag{3}$$

Eliminating i and i_2 from these equations we obtain

$$\frac{d i_1}{dt} + \frac{g}{C} i_1 = \frac{E}{C R r} \tag{4}$$

where $$g = \frac{R + r}{R r} = \frac{1}{R} + \frac{1}{r}$$

The solution of this differential equation is

$$i_1 = A \epsilon^{-\frac{g}{C} t} + \frac{E}{R + r} \tag{6}$$

where A is an integration constant to be determined by boundary conditions.

From (2) and (6)

$$e_c = A R \epsilon^{-\frac{g}{C} t} + E \frac{R}{R + r}$$

If we take the instant of the closing of the circuit as $t = 0, t = \dfrac{1}{f}$ at the instant of opening, f being the frequency, and the value of e_c at these two instants are respectively

$$|e_c|_{t=0} = A R + \frac{E}{R + r} \tag{7}$$

$$|e_c|_{t=\frac{1}{2f}} = A R \epsilon^{-\frac{g}{2fC}} + E \frac{R}{R + r} \tag{8}$$

Next consider the interval (half cycle) during which the circuit is open. Let us call this interval "Open half cycle."

During this half cycle the charge of C discharges through R and the equation of the circuit is

$$\frac{d e_c}{dt} + \frac{e_c}{C R} = 0 \tag{9}$$

the solution of this equation is

$$e_c = A' \epsilon^{-\frac{t}{CR}}$$

where A is an integration constant to be determined by boundary conditions.

If we take the instant of the opening as $t = 0$, the instant of the closing is $t = \dfrac{1}{2f}$ and the values of e_c at two instants are respectively

$$|e_c|_{t=0} = A' \tag{10}$$

$$|e_c|_{t=\frac{1}{2f}} = A' \epsilon^{-\frac{1}{2fCR}} \tag{11}$$

After the steady state of the circuit is established, the values of $|e_c|_{t=0}$ and $|e_c|_{t=\frac{1}{2f}}$ of the closed half cycle must be equal to the values of $|e_c|_{t=\frac{1}{2f}}$ and $|e_c|_{t=0}$ respectively of the closed half cycle, so that (10) and (11) must be identical with (8) and (7) respectively, *i. e.*,

$$A' = A R \epsilon^{-\frac{g}{2fC}} + E \frac{R}{R + r}$$

and $$A' \epsilon^{-\frac{1}{2fCR}} = A R + \frac{R}{R + r} R$$

Eliminating A' from these two equations, we have

$$A = - \frac{E}{R + r} \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{g + 1/R}{2fC}}}$$

Putting this value of A into (6) and replacing g by $1/R + 1/r$ we have for the value of i_1 during the closed half cycle·

$$i_1 = \frac{E}{R + r} \left\{ 1 - \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fC}(2/R + 1/r)}} \epsilon^{-1/C\,(1/R + 1/r) t} \right\} \tag{12}$$

From this equation and (1), we have for the closed half cycle

$$i = \frac{E}{R + r} \left[1 + \frac{R}{r} \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fC}(2/R + 1/r)}} \epsilon^{-1/C\,(1/R + 1/r)\,t} \right] \tag{13}$$

If I be the value of steady current through galvanometer or the value of i when there is no interruption of circuit, then

$$I = \frac{E}{R + r}$$

Therefore the ratio of i and I or instantaneous current to steady current through galvanometer for any particular time t during the closed half cycle is

$$\frac{i}{I} = 1 + \frac{R}{r} \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fC}(2/R + 1/r)}} \epsilon^{-1/C\,(1/R + 1/r)\,t}$$

$$= 1 + \alpha \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fCR}(2 + \alpha)}} \epsilon^{-\frac{1}{2fCR}(1 + \alpha)\,2ft} \tag{14}$$

where $\alpha = R/r$

If we denote the time by degrees of the electrical angle D,

$$t = \frac{1}{2f} \frac{D}{180}$$

Putting this value of t into (**14**) we have

$$\frac{i}{I} = 1 + \alpha\, \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fCR}(2+\alpha)}}\, \epsilon^{-\frac{1}{2fCR}(1+\alpha)\frac{D}{180}} \qquad (15)$$

This equation gives the ratio of instantaneous to steady current through galvanometer for any particular

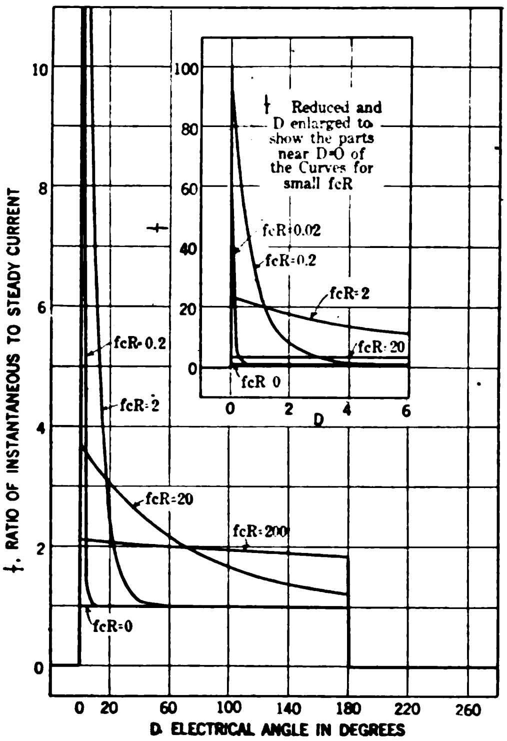

FIG. 18—WAVE FORM OF CURRENT THROUGH GALVANOMETER, R SHUNTED BY C, COMMUTATOR IN SERIES. CALCULATED BY EQUHTION (15.) $\alpha = R/r = 100$.

position of brush during closed half cycle. The value of this ratio for the open half cycle is, of course, zero.

This equation shows that i/I for any particular value of D is function only of $f\,C\,R$ and α.

In Fig. 18 curves between D and i/I computed from equation (**15**) for $f\,C\,R = 0.02, 0.2, 2, 20$ and 200 farad ohm sec.$^{-1}$ and $\alpha = 100$ are given. Corresponding curves as observed are given in Figs. 7 and 8.

The ratio of mean value of i during one cycle to steady current I, or the ratio of running to standstill deflection, S, is as follows:

$$S = \int_0^{1/2f} \frac{i\,d\,t}{I\,1/f}$$

$$= f\int_0^{1/2f} \left[1 + \alpha\, \frac{1 - \epsilon^{-\frac{1}{2fCR}}}{1 - \epsilon^{-\frac{1}{2fCR}(2+\alpha)}}\, \epsilon^{-\frac{1}{2fCR}(1+\alpha)2ft}\right]dt$$

by (**14**)

$$\therefore S = \frac{1}{2}\,\frac{f\,C\,R}{1 + 1/\alpha}\,\frac{\left(1 - \epsilon^{-\frac{1}{2fCR}}\right)\left\{1 - \epsilon^{-\frac{1}{2fCR}(1+\alpha)}\right\}}{1 - \epsilon^{-\frac{1}{2fCR}(2+\alpha)}} \qquad (16)$$

It is seen from equation (**16**) S is also a function only of $f\,C\,R$ and α.

Fig. 19 shows the close agreement between the observations and theory, the drawn curve shows the values

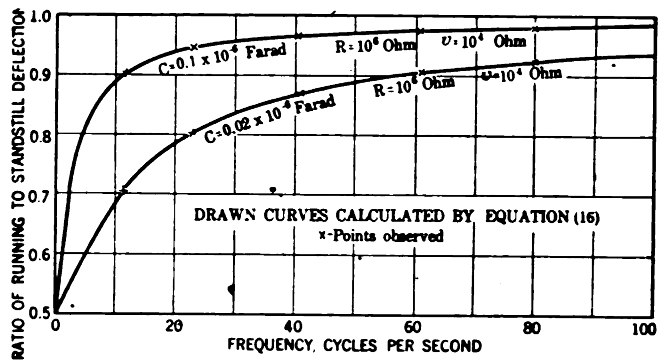

FIG. 19—CURVES BETWEEN FREQUENCY AND RATIO OF RUNNING TO STANDSTILL DEFLECTION. COMMUTATOR IN SERIES

calculated by formula (**16**) and the points marked are those taken from Fig. 4, the results of observation. The values of capacity are 0.02, and 0.2 microfarad which is so large that the capacity between commutator segments does not cause appreciable error.

II. A similar analysis shows that capacity between the leads to the commutator has very closely the same effect as capacity in shunt to R; see Figs. 4 and 5.

PICTURES AT THE SEA'S BOTTOM

Details of the method by which a remarkable photograph of the wrecked Laurentic was taken at the bottom of the Atlantic Ocean, off the Donegal coast, are given in a recent issue of *The London Times*. The camera was inclosed in a water-tight iron tank, tested to stand pressure twenty fathoms deep in water, and fitted with a vessel's porthole glass. A diver took it down, and electric bulbs were lowered from the Admiralty salvage steamship to provide light for the picture. After exposure of an hour and a half it was found that an admirable photograph of the wreck had been obtained. The experiment is regarded as a unique instance of successful deep-sea photography.

It is announced that the world's greatest radio station, with aerials swung upon eight 900-ft. steel towers, was completed at Bordeaux by the United States and will be in operation next Spring.

The Accuracy of Commercial Electrical Measurements

BY H. B. BROOKS

Physicist, U. S. Bureau of Standards

MEASUREMENT runs through the whole structure of engineering. A sufficient degree of maintained accuracy of measurement is essential. Uniform and logical guarantees or statements of accuracy should be used.

Maintained accuracy requires that instruments of the most suitable operating principle be procured from a competent and experienced maker, and be correctly installed and properly used, maintained and tested. These points are discussed in detail. The advantages of uniform wattmeter scales and square-law voltmeter scales are given, with experimental data.

The accuracies stated or guaranteed by American makers range from 2 per cent of full scale value in small switchboard instruments up to 0.1 per cent in laboratory standard instruments.

Electrical instruments have relatively delicate parts and small operating forces, and must be carefully handled if accuracy is required. They should not be overloaded nor exposed to strong magnetic fields.

The effect of room temperature changes on the accuracy varies from nearly 0.4 per cent per degree cent. in millivoltmeters having the circuit almost entirely of copper to a practically negligible value in the moving iron ammeter and in properly compensated d-c. voltmeters and electrodynamic wattmeters. Self-heating of instruments will cause errors unless suitable ventilation is provided.

Stray magnetic fields affect the accuracy of instrument readings, in some types to a serious extent. Induction and hot-wire instruments are only slightly affected. Methods of eliminating errors from this source are given, and curves showing the magnitude of the errors (up to 1.5 per cent) in d-c. instruments due to stray fields from neighboring instruments. Modern American practise is to surround the operating systems of electrodynamic instruments with a soft-iron shield to protect them from stray field. An unshielded electrodynamic voltmeter or wattmeter may be used to determine the strength of the field at any point.

Errors may arise from electrostatic forces acting on the moving parts of instruments. Various ways are described and means of obviating the trouble are given.

Unbalance in the moving system of instruments introduces errors. Means for checking the balance and for balancing the system are described. Maintenance of balance in service is favored by high torque, light weight, rigidity of construction, and avoidance of excessive temperatures.

Permanent magnets in instruments and meters should have the minimum possible reluctance in the air gap. A formula is given for the minimum relation for satisfactory permanence.

Springs should not have a fiber stress exceeding 600 kg. per cm.[2] Zero shift may be transient or slowly progressive. Zero adjusters are becoming general, but introduce danger of errors unless limited in their action.

Torque-weight ratio in indicating instruments should not be below 0.05 in portable instruments, 0.15 in switchboard instruments (units, g. and g-cm.)

Instruments should be designed with the smallest possible losses compatible with adequate torque. When the losses in instruments need to be taken into account, the method of connection should be such as to minimize the error if losses are not allowed for.

Good connections within instruments are essential. Poor connections are revealed by bridge measurements. Contact keys, spring abutments and scales are important details.

The permanent-magnet moving-coil voltmeter is the standard for d-c. measurements. Commercial instruments are available with full scale deflection as low as 20 millivolts and as high as 15 kilovolts, but both extreme values have limitations.

A voltmeter draws current and disturbs the potential difference which it is desired to measure. By taking a second reading with the voltmeter shunted by a resistance equal to its own, the true potential difference may be found by a simple formula. The "pyrovolter" and the "compensated indicator" accomplish the same result in different ways.

The moving-iron voltmeter seems to have the preference for switchboard use. The electrodynamic voltmeter is better for laboratory work. Hot-wire and thermocouple instruments are necessary for radio frequencies. Low-range a-c. voltmeters take an excessive current, which is often difficult to allow for. A two-range ammeter may be used as a compensated ammeter when such low-range voltmeters are used in parallel with a load.

Voltage (potential) transformers up to 30 kilovolts are tested by the potentiometer method for ratio and phase angle. Above 30 kilovolts the accuracy obtainable falls off, and the ratio cannot be computed accurately from winding data obtained at lower voltages. The "tertiary coil" is not believed by the writer to be a solution of the difficulty. Crest voltage measurements are becoming of increasing importance, and there is reason to believe that the corona voltmeter is an accurate instrument for this purpose.

The permanent-magnet moving-coil ammeter is the standard for all direct-current measurements but dry-cell and automobile work. Self-contained ammeters have no leads to cause trouble, but separate-shunt ammeters are more flexible in use. Shunts should be adjusted to standard drops. Ammeters are regularly listed with full scale value from 600 micro-amperes up to 20,000 amperes.

Abstract of a paper to be presented at the Midwinter Convention of the A. I. E. E., New York, February 20, 1920.

When an ammeter is connected into a circuit, the current previously flowing is altered to an unknown extent by its resistance. By taking a second reading after inserting an added resistance equal to that of the ammeter, the original value of current may be readily found.

Moving-iron ammeters are the most generally used for switchboard work. Above 600 amperes, current transformers must be used. The ratio of the currents varies with frequency, current strength, and the connected impedance (secondary burden). Current transformers of higher quality are required for power or energy measurements. Interconnection of secondaries is undesirable for accurate work.

The electrodynamic wattmeter is the standard instrument for a-c. power measurements. Compensated wattmeters automatically correct for instrument losses, but need to be carefully checked to see that the compensating coil is properly located with respect to the fixed coil. Self-inductance produces an error at low power factors. The usual correction factor is given, also the Drysdale additive correction, which the writer considers superior to the correction factor. Numerical examples are given, using actual wattmeter data. The method of compensating for self inductance by capacity is described and its limitations examined. A correction factor is derived for the effects of both self and mutual inductance, and illustrated by examples. The effect of eddy currents in the fixed parts of the wattmeter is two-fold, one part simply tending to reduce the reading, the other acting in opposition to the self inductance.

Polyphase wattmeters cannot be made as accurate as the corresponding single-phase wattmeters, on account of slight differences in the scale law of the two elements. Polyphase measurements are usually made with the two-wattmeter method. Corrections may in general be made more readily if three wattmeters are used, but for balanced loads there is no advantage in using more than two. The use of instrument transformers with wattmeters requires corrections for the ratio and phase angle errors of the transformers. The phase angles of the transformers may be lumped with those of the wattmeter.

Voltage transformers tested over a period of ten years by the Bureau of Standards showed phase angle errors ranging from 2 min. to 69 min. at no load, —38 min. to + 62 min. at full load. Current transformers should not have phase angles exceeding 1 deg. to 1 deg. 30 min. at 60 cycles, 1 deg. 30 min. to 3 deg. at 25 cycles, both at 0.5 ampere secondary. Good current transformers with small secondary burden will average about one-half the above values.

Some of the principal factors affecting the accuracy of electrical energy measurements are briefly discussed. Accuracy curves of both d-c. and a-c. watthour meters droop at overloads, the former because of heating of the armature by the field coils, the latter because of the braking action of the flux from the current magnet. Change of room temperature by 1 deg. cent. should not affect the accuracy of a good d-c. watthour meter more than 0.1 per cent, and a still smaller amount for the induction watthour meter. Direct-current watthour meters are seriously affected by stray field; induction meters to a very much smaller extent. Both d-c. and a-c. watthour meters run more slowly at higher voltages, the former because of heating of the voltage circuit, the latter because of increased braking by the flux from the voltage magnet.

The induction meter can be made fairly independent of frequency changes at unity power factor or of power factor changes at a fixed frequency, but errors result when both frequency and power factor vary. Changes of wave form may cause errors; values of 3 per cent and 15 per cent are cited.

Ratio and phase-angle errors of instrument transformers affect energy measurements just as they do power measurements, but the watthour meter can be adjusted to correct for an average value of each of these errors.

Portable watthour meters are equivalent to service meters except as to register, connections, and case. They should be carefully handled and frequently checked. The d-c. meter is sensitive to local fields, and should be oriented (by means of a compass) so as to avoid error due to such fields. Portable a-c. watthour meters have much better operating characteristics than the d-c. meters.

Further developments which are desirable are briefly discussed, as follows: The user should have a better understanding of accuracy requirements, and the maker should give more data on the subject, and more definite statements or guarantees of accuracy. All instruments should be marked with a symbol to show the operating principle. There should be an American specification for instrument accuracy similar to the one put out by the British Engineering Standards Committee. Desirable materials include a magnet steel of greater coercive force and spring materials having less elastic fatigue. Voltage transformers for high voltages should be smaller and less expensive, and means for obviating or allowing for electrostatic effects on ratio and phase angle should be found. Current transformers as now made are the most unsatisfactory link in the chain of devices used for metering a-c. energy, and much better ones should be made available, so that meters could be adjusted to be accurate on the secondary energy. Special instruments are needed for plant acceptance tests, which will do for a-c. power what the deflection potentiometer does for direct current and voltage. Radical improvements are needed in the d-c. commutator meter. For important a-c. metering installations a much more accurate meter should be made, even at the expense of much greater weight and cost. To accomplish this, the braking flux due to permanent magnets should be very largely increased, and a very much higher grade of steel should be developed for use in the voltage magnet.

Introductory Remarks on Present Theories of Atomic Structure

BY SAUL DUSHMAN

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Introduction

THERE is probably no problem in physics and chemistry at the present time that is of greater interest than that of the structure of the atom. During the past few years especially, a number of the foremost investigators in both physics and chemistry have been speculating upon this problem, and while their views cannot by any means be stated to be in agreement, yet they are of exceeding interest and probably contain in each case an element of the great truth which will probably emerge in the next few years.

It has recently been stated that, "A theory in physics is a policy, not a creed." This is the point of view from which we must regard at the present time all theories of the structure of the atom. In the ultimate analysis, a theory is a generalization that correlates a number of experimentally observed facts. The more numerous the facts "explained" by a theory, the more useful it becomes as a means for the further advancement of scientific knowledge, but it may yet be far from the real explanation of all the phenomena which it is intended to correlate.

In approaching the problem of atomic structure, we must therefore first of all attempt to obtain a perspective, as it were, over the immense number of facts that we know about the atom, and knowing these it may perhaps be possible to draw some conclusions as to the values of the different theories which have been proposed for the structure of the atom. While this problem has, until recently, been attacked almost altogether from the point of view of the physicist, and chemical considerations have been given secondary place, it will simplify the discussion of the subject if we reverse the order in the following remarks and deal with the chemical point of view first.

Periodic Law

Chemical Evidence of Complexity of Atomic Structure. For the chemist, the atom itself has hitherto represented the ultimate unit in the structure of matter in which he was interested, and naturally a large number of observations have accumulated with regard to the properties of the atoms of the different elements. Now the most significant fact about all these elements is that it is possible to arrange them in groups so that the members of any one group are much more alike in physical and chemical properties than any two members from two different groups. The periodic law enunciated by Mendeljeff in 1871 states that the properties of the elements, and the properties and compositions of compounds, vary periodically with the atomic weights of the elements. The arrangement of the elements, based on this law, and including those which have been discovered since the above date, is shown in Fig. 1.

There is probably no series of observations bearing on the question of atomic structure that is of greater importance than those which are embodied in the periodic table of the elements.

When the elements are arranged in order of increasing atomic weight, it is observed that among the first twenty elements, there is a repetition to a large extent of physical and chemical properties at every eighth element. Thus sodium resembles lithium; phosphorus, nitrogen and chlorine, fluorine. Beginning with argon, we have to pass over eighteen elements before we come to an element similar to it, and then we have another group of eighteen before we reach xenon which is the next homologue to krypton and argon. Thus, leaving hydrogen and helium out of consideration for the present, we have two series of eight elements and then two series of eighteen. In the series beginning with xenon, however, there occurs a sort of pleiadic system between cerium and tantalum. All these elements are known as the "rare earths." Most of them are so nearly alike chemically and physically that their separation is a matter of extreme difficulty. Evidently there is some fact connected with the structure of the atom which makes the existence of such a group possible when we get to elements whose atoms are heavier than those of cerium. As the atoms increase in mass, the structure becomes more and more complex and finally we obtain a series of elements whose atoms are capable of spontaneous disintegration and thus form the group of radioactive elements.

When Mendeljeff arranged his elements in order of increasing atomic weight, he found that tellurium and iodine apparently did not follow in the order which they should follow according to their chemical and physical properties. Thus, while iodine is very similar to chlorine and fluorine, and tellurium is similar to oxygen and sulphur, the latter has an atomic weight greater than that of iodine. The same discrepancy occurs in the case of argon and potassium. For a long time it was thought that the discrepancies were due to wrong atomic weight determinations, but innumerable investigations have shown that the values as given in Fig. 1 are accurate to less than one-tenth per cent.

The most significant fact brought out by Mendeljeff's arrangement is the gradual change in valency

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as we pass in each series from the elements of low atomic number to those of higher numbers. The elements of group O are chemically inert; they cannot so on. The elements of the fifth, sixth and seventh groups possess two kinds of valencies. With H they form compounds of the types EH_3, EH_2 and EH

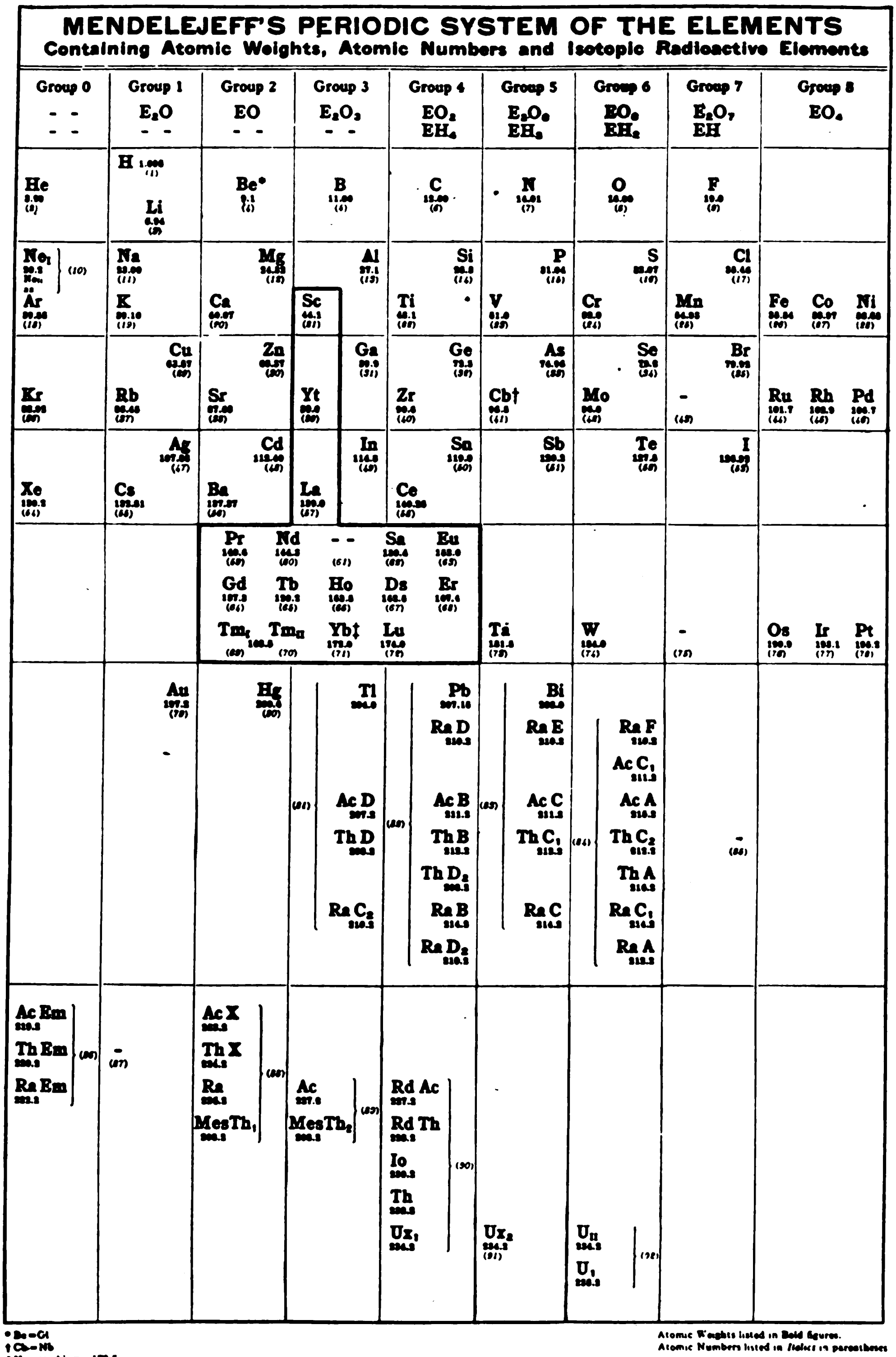

FIG. 1

be made to react with any other elements. They are therefore assigned the valency O. Elements of Group 1 are monovalent (forming compounds of the general type E_2O); those of Group 2 are divalent, and respectively, while with oxygen and more electro-negative elements they are able to form compounds of the types E_2O_5, EO_3 and E_2O_7 respectively.

Not only do the elements exhibit this periodical

recurrence of chemical properties, but they exhibit the same periodic recurrence in most of their physical properties. Fig. 3 illustrates this in the case of the cohesional properties. Those elements which belong to the same group in the periodic table occupy corresponding positions on each of the curves.

When a solution of copper chloride is electrolyzed, copper is deposited at the cathode, that is, the electrode which receives negative electricity, while chlorine is liberated at the anode. Copper is therefore said to be electro-positive, while chlorine is electro-negative. In a Daniel cell, when the plates are joined by a wire, the zinc goes into solution and the copper becomes plated with more copper from the solution. Since the current flows in the wire from the copper to the zinc, we say that the copper is electro-positive with respect to the zinc.

Now it is extremely significant that the most electro-positive elements occur in Group 1, while the most electro-negative ones occur in Group 7; furthermore, in each group the electro-positive property increases with increase in atomic number, so that Cs is much more electro-positive than Li, while I is much less electro-negative than F. Also, the elements of Group 1 combine readily with those of Group 7, the reaction being often quite energetic. The compounds so produced are extremely good electrolytes in aqueous solution and react readily, when in solution, with other salts. As we proceed from Group 1 to Group 7, the electro-positivity decreases, and in Group 5 we find more or less pronounced electro-negative elements, the electro-negativity finally reaching a maximum in Group 7.

Not only do the elements exhibit this periodical recurrence of chemical and electrochemical properties, but they exhibit the same periodic recurrence in most of their physical properties. The Journal of the American Chemical Society in 1915 published a series of curves illustrating cohesional properties of the elements, showing that those elements which belong to the same group in the periodic table occupy corresponding positions on each of the curves.

The Periodic Table thus represents a summary of all the facts that we know about the properties of the chemical elements and their relationships. It is evident that the periodicity exhibited by the elements must be due to some periodicity in the structure of the atom itself. However, the chemist was until very recently not very much interested in pursuing the problem any further, and even if he were interested, the ordinary chemical methods are not adapted for attacking the problem.

Physical Evidences of Complexity of Atomic Structure

The physicist, on the other hand, has found himself confronted all the time by observations which are explicable only by assuming the atom itself to be more or less complex. Naturally, as the facts have accumulated, previous theories have been found to be no longer tenable and these have been either modified or discarded completely. It is impossible in a brief review such as this to deal with all these theories at length, or even to discuss all the fundamental facts, the observation of which have led to the transition from one theory to another. All we can attempt is to review briefly the more prominent facts upon which present views of atomic structure have been based.

The first observations which led physicists to speculate on the structure of the atom were probably those made on the emission and absorption spectra of the different elements. Here we see the atoms emitting and absorbing different types of electromagnetic radiations, and the most obvious suggestion from the physicist's point of view would be that these spectra are due to electric charges executing periodic orbits in the atom.

Atomic Theory of Electricity

The Electron. However, the experiments of Crookes on the electric discharge in gases at very low pressures may be considered as the pioneer investigation in developing our present theory of the constitution of the atom. "He found that, regardless of the nature of the residual gas in the exhausted tube or the nature of the cathode, the rays which are given off at the cathode consist of particles moving in straight lines, that they produce a brilliant glow on phosphorescent subtances, that they exert a mechanical force and generate heat rapidly when intercepted, and that their trajectory is altered by the influence of a magnet."[1]

These discoveries were published in 1879. In 1895 came the discovery of X-rays by Roentgen. When the cathode rays are stopped by matter of any kind, X-rays are produced. The interest in the cathode rays became greater than before, and J. J. Thomson set himself to investigate the nature of the carriers of electricity in these rays. He was able to show that the cathode rays actually consist of *negatively charged* corpuscles (as he designated them), which, starting from the cathode, move with very high velocities in straight lines and produce a vivid fluorescence wherever they strike the glass walls of the tube. Now it was shown a long time ago by Rowland that a charged particle in motion must produce the same effects as are observed in the case of a wire carrying current. In other words, the direction of motion of a charged particle will be effected by magnetic and electrostatic fields, just as a wire carrying current. Furthermore, the magnitude of the effects observed depends upon the ratio of the charge (ϵ) to the mass (m) of the particles and upon their velocity. By observing the amount of de-

1. W. L. Hardin. "The Nature of the Chemical Atom," *Science*, November 10, 1916.

flection suffered by the cathode rays when subjected to magnetic and electrostatic fields, J. J. Thomson concluded that for the negatively charged corpuscles constituting these rays, ϵ/m has a value of about 1.2×10^7 e.m.u. per gm. Later experiments have led to the more accurate value 1.766×10^7. The velocity of the corpuscles was found to vary from 10^7 to 10^9 cm. per sec.

Now let us consider what these results mean. In the case of the electrolysis of a solution of HCl, it requires 96,500 coulombs, or 9650 e.m.u. to liberate 1.008 gm. of hydrogen. The ratio ϵ/m for hydrogen ion ($\overset{+}{H}$) in electrolytes is therefore 9573 e.m.u. per gm. Hence, either the unit electric charge on the corpuscle is almost 2000 times greater than on a hydrogen atom in electrolysis, or the mass of the corpuscle is 2000 times smaller than that of a hydrogen atom.

Now, apart from the evidences obtained by a large number of investigators that the corpuscles constituting the cathode ray beams must have masses much smaller than that of a hydrogen atom, there are definite reasons for believing that the unit electric charge in the cathode ray discharge has the same value as that possessed by the charged hydrogen atom in electrolytic conduction. We must therefore conclude that the mass of the negatively charged corpuscle is

$$\frac{9573}{1.7666 \times 10^7} = \frac{1}{1845}$$

of that of the hydrogen atom.

The most accurate determinations of the charge on an electron are those obtained by Prof. Millikan at the University of Chicago.
According to his measurements

$$\epsilon = 1.591 \times 10^{-20} \text{ e.m.u.}$$

Hence, the mass of the cathode ray corpuscle

$$m = 9.01 \times 10^{-28} \text{ gm.}$$

whereas the mass of a hydrogen atom is

$$M^H = \frac{1.008}{6.062 \times 10^{23}} = 1.663 \times 10^{-24} \text{ gm.}$$

Electron Emission from Hot Bodies

Photo-Electric Effect. The cathode rays of an ordinary discharge tube such as is used for the production of X-rays, is not the only case in which these negatively charged corpuscles, or *electrons*, as they have been designated, are obtained in the free state. O. W. Richardson and others have shown that heated metals emit negatively charged corpuscles with the same value of ϵ/m as that obtained for cathode rays. The number of electrons emitted per unit area of surfaces increases with the temperature according to a relation which has the same form as that which expresses the rate of variation with temperature of the number of molecules given off by a liquid (vaporization). This would indicate that the electrons may be regarded as "evaporating" from a heated metal, and as a matter of fact, the latent heat of vaporization of the electrons has been measured for a number of metals. The interesting fact has been observed that when the metals are arranged in the order of increasing latent heats, we obtain the order of the metals in the ordinary Volta series, the most electropositive metals having the highest values for the latent heat of vaporization.

Electrons are also emitted from all metals under the influence of ultra-violet light. This is the well known photo-electric effect. The more electro-positive the metal, the lower the frequency of the light that is capable of causing photo-electric emission, and in the case of the alkali metals photo-electric currents of considerable magnitude are obtained even when ordinary light is used as a source of illumination.

These facts lead to the conclusion that the atom of all metals must contain electrons as an essential constituent.

Radioactive Phenomena

We must now turn to the consideration of another series of discoveries which has served to indicate the complex structure of the atom.

Shortly after the discovery of X-rays by Roentgen, a number of elements were discovered by Becquerel, Mme. Curie and others which possess the exceedingly interesting property of blackening a photographic plate. Further investigation showed that in general these elements emit three distinct types of radiation, characterized by the following properties:

(1) *β-rays.* From the magnitude of the deflection of these rays in a magnetic field, the conclusion was drawn that they are essentially the same as cathode rays, that is, they consist of streams of electrons, but their velocities are very much greater, so that in a number of cases they approach the velocity of light.

(2) *α-particles.* These are deflected in a magnetic field in the opposite direction to β-rays, and must therefore be *positively* charged. Further investigations have shown that these α-particles have the same mass as the helium atom, and carry *twice* the electric charge possessed by an electron.

(3) *Y-rays.* Recent investigations have led to the conclusion that these are of the same nature as X-rays, that is, electromagnetic radiations, but their wave lengths are much shorter than those of ordinary X-rays.

A study of the behavior of these so-called radioactive elements by Rutherford and Soddy led them to suggest the theory that the atoms of these elements are continually undergoing spontaneous disintegration and forming atoms of elements which possess totally different chemical and physical properties from those of the parent elements.

After a certain average period of existence, which

may range from over 10^9 years, as in the case of uranium (U_1), to less than 1 minute, as in the case of thorium emanation, the atom undergoes a sudden explosion and yields another atom which possesses totally distinct properties. Further investigation has shown that the rate at which these atoms disintegrate is absolutely uninfluenced by any of the factors, such as temperature, pressure, illumination with ultra-violet or X-rays, etc., which are used in controlling the rate of ordinary chemical reactions.

It has been found that each of the radioactive products belongs to one of three well-defined disintegration series whose starting points are uranium, thorium, and actinium respectively. The most noteworthy feature about these products is the fact that individual members of each series appear to be chemically indistinguishable from certain members of the other series. Hence, according to the chemist's definition, they belong to the same element. Owing, however, to the difference in previous history of these atoms, they possess different atomic weights and also differ in period of existence. Soddy, who has drawn attention to these cases, has named these products isotopes, since they occupy the same place in the periodic table. As shown in the table in Fig. 1, there are three other isotopes of thallium, and no less than six isotopes of lead.

These observations point to the conclusion that not only are the atoms of a large number of elements extremely unstable, but also that the atomic weight is not as important a characteristic of any one element as has been previously considered. In fact, the atomic weight of an element is of secondary importance, and there is some other property of the atom which is of much greater significance.

Nuclear Theory of the Structure of the Atom

Light was thrown on this problem by a number of classical investigations in Rutherford's laboratory in 1911. When high velocity electrons or alpha particles are projected at a thin piece of gold foil, they are deflected in such a manner as to indicate that some of them have been subjected to very intense electric fields within the atoms of gold. Furthermore, observations on the angles at which these electrically charged particles are deflected lead to the conclusion that in some cases anyway they must have penetrated to within 10^{-12} cm. from the centre of the atom before being deflected. Now as the average atomic radius is about 10^{-8} cm., this result would indicate that the atom consists of a very intense positive charge of extremely small dimensions (less than 10^{-12} cm.), or nucleus, at the center, and a number of electrons equivalent to this total positive charge situated at different distances from the latter, thus forming, as it were, a miniature solar system. From the measured deflections, Rutherford also concluded that the number of electrons present in any atom is about one-half the atomic weight.

The most signal confirmation of Rutherford's nuclear theory of atomic structure was obtained by Moseley in 1913. As has been mentioned already, X-rays are produced by the projection of high velocity electrons against a metal used as anti-cathode or anode. It was suggested by Laue that these X-rays are really of the same nature as ordinary light waves and the electromagnetic waves used in wireless transmission, but of such extremely short wave-lengths that even the finest diffraction grating cannot be used to measure these, and in order to confirm this theory he thought of making use of a crystal surface in which presumably the atoms are arranged at regular distances. Such a crystal would therefore present a natural grating whose lines instead of being 10^{-4} or 10^{-5} cm. apart are 10^{-8} cm. apart, or 1000 times closer than in the most delicate grating that can be ruled by machine. By this means Laue was able to demonstrate that X-rays are simply an extension of electromagnetic radiation to extremely short wave-lengths about 1000 times smaller than those of ordinary or visible light. Bragg extended Laue's work and showed how the wave-lengths of the X-rays could be measured very accurately.

Now Moseley set himself to investigate the nature of the X-rays emitted by all the elements from aluminum to gold when these are made anti-cathodes in an X-ray tube. With sufficiently high voltages, each element emits two characteristic bands of X-rays which have been designated the *K*- and *L*- radiations respectively. Moseley measured photographically the wave-lengths of the two lines (α- and β-lines) which compose the *K*-radiations of the different elements, and found this remarkable relation: For either the α- or β-radiation, the frequency (velocity of light/wave-length) increases in passing from any one element to one of higher atomic weight, and the order in which the elements can be arranged according to increase in frequency is the same as that which has been found to hold for the elements in the periodic table. Moreover, if N denotes the order of the element in the table ($H = 1$, $He = 2$, and so forth), the frequency of any one line may be expressed by a relation of the form

$$\sqrt{\nu} = a(N - N_0)$$

where a and N_0 are characteristic constants for this radiation.

The fact that such a relation exists which enables us to determine the atomic number, N, for each element and that this atomic number coincides in all cases with the order in which the element must be placed in the Periodic Table in accordance with its physical and chemical properties, must be regarded as one of the most important discoveries in recent years. Not only does it add a new significance to the Periodic Table, but it also throws much light upon the whole problem of atomic structure. For, according to Rutherford the atomic number signifies nothing more or less than the magnitude of the positive charge

on the nucleus of the atom, and hence N corresponds also to the actual number of electrons in the atom, since the number of negative charges in a neutral atom must be equal to the total positive charge.

GENERAL CONCLUSIONS REGARDING ATOMIC STRUCTURE

On the basis of these observations and from what we know of the chemical properties of the elements, we may therefore attempt to draw some conclusions with regard to the structure of the atom itself.

Firstly, the atom must be constituted of a positive nucleus of extremely small dimensions (but approximately equal in mass to the atom itself), and a number of electrons distributed presumably in one or more rings or spherical shells outside the nucleus, the total number of electrons being equal to the positive charge on the latter. Secondly, all the physical and chemical properties of the atom (excepting radioactive and gravitational) are governed solely by the magnitude of this charge on the nucleus (or atomic number).

This conclusion is based on the observations, already mentioned, that in the case of radioactive elements, we may have atoms of different atomic weights, but occupying the same place in the Periodic Table (isotopes), thus indicating that the members while possessing different atomic weights are identical in all their chemical properties and most of their physical properties as well.

Since the disintegration of any atom always yields an atom occupying a different place in the periodic table, we must conclude that the change actually occurs in the nucleus itself. Furthermore, as electrons and alpha particles are emitted during the disintegration, it follows that the nucleus, small as it is, consists of negatively charged corpuscles and helium nuclei, packed close together. How is it possible for positive and negative charges to remain in equilibrium under such conditions? Probably Coulomb's law fails completely for distances as small as those which exist inside the nucleus. It may indeed become reversed; that is, positive and negative charges repel each other at distances which are less than 10^{-13} cm.

Thirdly, in order to explain chemical combination and periodic properties, we must assume that there are two classes of electrons, an inner and outer set. The outer ones are the electrons which are active in chemical combination and conduction of electricity through metals. They are the so-called valency electrons. The number of electrons in this outer set undergoes periodic changes in value as the atomic number increases, and the maximum number of electrons which are stable on the outer surface of the atom is eight, or eighteen, thus accounting for the periodicity of eight and eighteen in Mendeljeff's table.

The outer electrons are also those which are active in the production of ordinary emission spectra. If Lorentz's explanation of the Zeeman effect is right, and it is the only one that explains the phenomenon quantitatively, then we must conclude that the lines visible in ordinary emission spectra are due to the vibration of electrons with frequencies ranging around 10^{15} per second. The fact that these emission spectra are modified by method of excitation and also differ with different compounds, shows that the electrons producing these phenomena are near the surface of the atom and therefore probably the same as the valency electrons.

On the other hand, the inner electrons are unaffected by ordinary methods, but high velocity electrons may stimulate them and thus produce the high-frequency spectra observed by Moseley and others. As pointed out by Kossel[2], the continuity of the K-line spectra for the different elements from the lowest atomic number to the highest, shows that the periodicity observed in the outer electrons does not extend to the innermost.

It will be observed that in drawing these conclusions, we have merely made use of a number of experimental facts, and tried to correlate them by means of a simple physical representation. Such questions as the exact distribution of the electrons, whether in two dimensions or three, whether rotating or stationary, and furthermore the question of the law of force which must subsist between electrons and nucleus in order that the atom shall remain stable—all these problems have not been touched upon at all. It is therefore natural that different theories of atomic structure should diverge in regard to the answers suggested for these questions.

The first atom model which represented a serious attempt to correlate the structure of the atom with its chemical and physical properties was due to Lord Kelvin. It was subsequently extended and developed by J. J. Thomson. Assuming the atom to "consist of concentric rings of negative electrons in a sphere of homogeneous positive electricity of the size of the atom," Thomson was able to show that such a model would be in complete accord with the known periodic properties of the elements.

The observations on scattering of alpha and beta particles mentioned above led Rutherford to propose a nuclear structure such as has already been described, and the work of Moseley, Darwin, and others have confirmed Rutherfords' views.

Now a similar atom model had been suggested some years ago by Nagaoka, but at that time the objection was raised that such an arrangement of electrons rotating around a positively charged center would be dynamically unstable. On the other hand, no such objection could be raised against the model of J. J. Thomson. Thus arose a strange situation in scientific speculations, that the actual observations led to conclusions which were apparently at variance with the classical laws of dynamics.

2. Ann. d. Physik, 49, 229 (1916).

Atom Model of Bohr

The most successful attempt to bridge this difficulty has been made by N. Bohr. In a series of classical papers which appeared in 1913 in the *Philosophical Magazine*, he showed that by introducing certain reasonable assumptions on the nature of the forces between the electrons and the positive nucleus, it is possible to deduce a very definite picture of the structure of atoms and molecules.[3]

After stating the nature of the difference between the atom-models proposed by Thomson and Rutherford, and the objections raised against the latter, Bohr continues as follows:

"The way of considering a problem of this kind has, however, undergone essential alterations in recent years, owing to the development of the theory of energy radiation, and the direct affirmation of the new assumptions introduced in this theory, found by experiments on very different phenomena, such as specific heats, photoelectric effect, Roentgen-rays, etc. The result of the discussion of these questions seems to be a general acknowledgment of the inadequacy of the classical electrodynamics in describing the behavior of systems of atomic size. Whatever the alteration in the laws of motion of the electrons may be, it seems necessary to introduce in the laws in question a quantity foreign to the classical electrodynamics, *i.e.*, Planck's constant, or as it is often called, the elementary quantum of action. By the introduction of this quantity (h) the question of the stable configuration of the electrons in the atoms is essentially changed."

In other words, Bohr reasons that just as it has been found necessary to introduce a quantum theory of energy emission in order to acccount for the observed laws of distribution of energy in the spectrum of a black body, even so it is reasonable to assume that in the case of electrons vibrating in the atom, there exists some sort of discontinuity in the emission and absorption of energy. In this manner, Bohr is able to give a mechanical basis to the atom-model proposed by Rutherford.

The principal assumptions made by him are as follows:

(1) That the electrons revolve in circular orbits about the positive nucleus, with an angular momentum which is the same for all the electrons in the atom, and that during such revolutions the electrons do not emit any energy, although such an emission is to be expected from ordinary electro-dynamics. These states in which the electrons are merely revolving are known as "stationary" states of the system under consideration, and in these states the relation between the frequency of rotation, the average kinetic energy of the electron, and the radius of the orbit (r) can be calculated by the laws of ordinary dynamics.

(2) When, however, an electron passes from one stationary state to another, that is, from one orbit to another, there is an emission or absorption of energy, and the radiation emitted during such a transition is homogeneous and possesses a frequency (ν) which is determined by the relation

$$h\nu = A_1 - A_2$$

where h is Planck's constant, and A and A_2 are the energies of the system in the two stationary states.

From these assumptions, Bohr deduces a number of interesting results. He is able to account qualitatively at least for the Rydberg-Ritz law for the frequency of the lines in the ordinary spectrum of an element, and in the case of the hydrogen spectrum he derives the well-known Balmer formula for the series

$$\nu = K\,(1_2/T_2 - 1_2/T_{11})$$

where T_1 and T_2 are integers and K is the Rydberg constant. Bohr's calculated value of this constant is 3.284×10^{15}, while the observed value is 3.29×10^{15}. The agreement must be considered one of the most wonderful achievements of the theory.

Bohr also shows that on the basis of his assumption, the configuration of any system of electrons, *i.e.*, the frequency and linear dimensions of the rings, is completely determined when the nuclear charge and the number of electrons in the different rings are given. The physical and chemical properties thus depend upon the nuclear charge. In this conclusion, Bohr therefore agrees with Moseley and indeed he shows that Moseley's relation between the frequency as derived from measurements of the X-ray spectrum, and the nuclear charge follows directly from his assumptions.

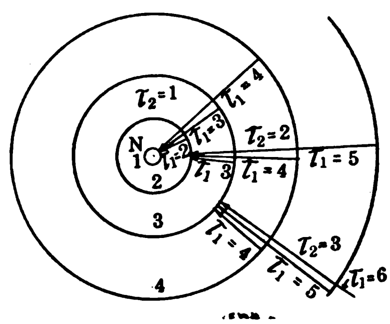

Fig. 2

The physical picture which Bohr would assign to the hydrogen atom may be illustrated by referring to Fig. 2.[4] "N represents the nucleus of the atom. The rings 1, 2, and 3 correspond to the orbits of the electron in the various steady states of motion. When an electron falls from one steady state to the next

3. *Phil. Mag. 26*, 1, 477, 857 (1913) also *30*, 394 (1915). An excellent review of the work of Bohr and Nicholson on the structure of the atom has been given by W. D. Harkins and E. D. Wilson, *J. Am. Chem. Soc. 37*, 1396 (1915). A summary of Bohr's theory has also been given by the writer in "Recent Views on Matter and Energy." *General Electric Review 17*, 1199 (Dec. 1914).

4. W. D. Harkins and E. D. Wilson, loc. cit.

one of small radius of vibration, one quantum of energy is liberated. In the fundamental spectral series, all the lines are formed by electrons falling from the second ring and beyond, all the way to the first ring. The first line in the series is due to an electron falling from the second to the first ring; the second line to an electron falling from the third to the first ring, and so on."

The different hydrogen series may be accounted for by assigning different values to T_1 and T_2 in the Balmer formula given above, and in the diagram Fig. 1, three such possible series are indicated. If $T_2 = 1$, and the values 2, 3 and 4 are assigned to T_1, we get a series which was not known at the time Bohr wrote his first papers, but which has since been found by Lymen in the Schumann region. "If $T_2 = 2$, and a series of values be assigned to T_1, the ordinary Balmer series for hydrogen results. For $T_2 = 3$, there results an infra-red series which was discovered by Paschen."

Bohr's most successful results have been obtained in dealing with atoms of hydrogen and helium. He has not extended his calculations much beyond the lithium atom, but he suggests the following possible scheme for the arrangement of the electrons in the lighter atoms. For each element the different numbers give the number of electrons in each ring, proceeding from the center outwards.

H	1				
He	2,	*Ne*	8, 2	*Ar*	8, 8, 2,
Li	2, 1	*Na*	8, 2, 1	*K*	8, 8, 2, 1
Bi	2, 2	*Mg*	8, 2, 2	*Ca*	8, 8, 2, 2
B	2, 3	*Al*	8, 2, 3	*Sc*	8, 8, 2, 3
C	2, 4	*Si*	8, 2, 4	*Ti*	8, 8, 4, 3
N	4, 3	*P*	8, 4, 3	*V*	8, 8, 4, 3
O	4, 2, 2	*S*	8, 4, 2, 2	*Cr*	8, 8, 4, 2, 2
F	4, 4, 1	*Cl*	8, 4, 4, 1	*Mn*	8, 8, 4, 4, 1

It will be observed that the elements are made to exhibit a recurring periodicity in the configuration of the electrons, which corresponds to the periodicity of chemical and physical properties. Also the number of electrons in the outermost ring corresponds in each case to the normal valency of the element.

While Bohr's assumptions have been questioned by a number of physicists and other views have been suggested notably by Nicholson and Thomson, yet it has been applied with a certain measure of success by Kossel to explain the periodic properties of the elements and the formation of chemical compounds and more recently Sommerfield, Born and Lande have attained marked success with it by showing how the elastic properties may be deduced from the Bohr model with only slight modifications in its assumptions.

However, Bohr's theory was certainly intended primarily to explain the origin of spectral series. As such it represents in the main the point of view of the physicist, and naturally fails in certain respects when tested from the chemist's point of view.

Theory of Atomic Structure by Lewis and Langmuir

In general, the chemists prefer to consider the valency electrons as fixed on the surface of the atom in definite positions, in contradiction with the assumptions made by Bohr and other physicists. There are innumerable observations in the field of organic chemistry, such as the existence of the asymmetric carbon atom and the phenomena of stereochemical hindrance, which lead to the conclusion that the valency electrons are stationary in the atom.

Moreover, some recent observations made by Dr. A. W. Hull of this Laboratory, on the structure of the iron atom, lend support to this theory.[5] He concludes from measurements of the intensities of the lines produced by allowing monochromatic X-rays to strike iron crystals, that "the electrons are displaced from the center of the iron atom along the diagonals of a cube in four groups of 2, 8, 8, 8, at distances 1/32, 1/16, 1/8, and 1/4 respectively of the distance to the nearest atom." That is, 24 electrons are arranged at the corners of three cubes, one fitting inside the other, with two electrons close to the center.

It is important to emphasize the fact that the choice by the physicists of an atom with rotating or vibrating electrons is due primarily to two causes: Firstly, in order to meet the requirements of dynamical stability, it is necessary to balance the attractive force between the electrons and the nucleus by some other force, and Bohr does this by assuming a centrifugal force due to the rotation of the electrons. This is quite similar to the case of the solar system where the gravitational force of attraction between the sun and the planets is balanced by the centrifugal force acting on the latter. Secondly, the assumption of rotating electrons offers a simple explanation of spectral series and as already shown above, Bohr has attained very marked success in this direction by such an assumption. On the other hand, if we assume the electrons to be stationary, it is necessary to assume that the electrostatic forces in the atom are balanced by some other forces than those due to rotation, and the most obvious assumption is that these are of electromagnetic nature.

A theory along these lines has been advanced by Parson.[6] He assumes that the electron itself is a rotating ring of negative electricity and is therefore a small permanent magnet; hence, the name *magneton*. The magneton at the surface of the different atoms exert magnetic and electrostatic forces on each other and thus lead to chemical combination. This theory necessitates, however, the existence of a uniformly charged sphere of positive electricity, as in the case of J. J. Thomson's model. Thus the arguments for

5. The method has been described by Hull in the *Physical Review* and by the author in "The Structure of the Atom," *General Electric Review*, 1917, pp. 496-7.

6. Smithsonian Inst. Report.

the atom with stationary electrons are weak from the physicist's standpoint, but very strong from the chemist's point of view. The latter has therefore frankly ignored this question of stability and is content to leave it for future solution.

The theory of an atomic structure with stationary electrons has been advanced tentatively by chemists at different times, but the first effort which attained any marked success is due to G. N. Lewis.[7] In order to account for the observed periodicity of the elements and the mode of formation of compounds, Lewis assumes that "the electrons arrange themselves in a series of concentric shells, the first shell containing two electrons, while all the other shells tend to hold eight. The outermost shell, however, may hold 2, 4, or 6, instead of 8. The eight electrons in a shell are supposed to be placed symmetrically at the corners of a cube or in pairs at the corners of a regular tetrahedron. When atoms combine they usually hold some of their outer electrons in common, two electrons being thus held for each chemical bond. These electrons may form parts of both atomic shells of eight electrons. By means of these postulates Lewis is able to give an extraordinarily satisfactory explanation of the periodic arrangement of the elements and to explain in detail most of their chemical properties. He confines his attention, however, exclusively to the inert gases, the alkali and the alkaline earth metals, the halogens, boron, aluminum, scandium, carbon, silicon, nitrogen, phosphorus, arsenic, antimony, bismuth, oxygen, sulfur, selenium, and tellurium, a total of 35 out of the 88 known elements."

Lewis' theory was published a couple of years ago, but did not attract the attention it deserves until very recently when Dr. Langmuir developed it still further and extended it to apply to all the elements.

"In attempting," he writes, "to determine the arrangement of electrons in atoms, we must be guided by the numbers of electrons which make up the atoms of the inert gases, in other words, by the atomic numbers of these elements, namely, helium 2, neon 10, argon 18, krypton 36, xenon 54, and niton 86."

Rydberg had pointed out that these numbers are obtained from the series

$$N = 2\,(+ 2^2 + 2^2 + 3^2 + 3^2 + 4^2 +)$$

The factor two suggests a two-fold symmetry and Langmuir therefore assumes:

Postulate 1. "That the electrons in the atoms of the inert gases are arranged about the nucleus in pairs symmetrically placed with respect to a plane passing through the nucleus which we may call the equatorial plane."

In order to account for the occurrence of the terms 1^2, 2^2, 3^2 and 4^2 in Rydberg's relation, it is necessary to assume:

Postulate 2. "That the electrons in the atoms are distributed through a series of concentric spherical shells. All the shells in a given atom are of equal thickness. If the mean of the inner and outer radii be considered to be the effective radius of the shell, then the radii of the different shells stand in the ratio 1: 2: 3: 4 and the effective surfaces of the shells are in the ratio 1: 4: 9: 16."

Postulate 3. "Each spherical shell is divided into a number of cellular spaces. The thickness of these cells measured in a radial direction is equal to the thickness of the shell and is therefore the same (Postulate 2) for all the cells in the atom. In any given atom the cells occupy equal areas in their respective shells. All the cells in an atom have therefore equal volumes. The first postulate, regarding symmetry applies also to the location of the cells. The first shell therefore contains two cells obtained by dividing the shell into two equal parts by the equatorial plane. The second shell having 4 times the surface (Postulate 2) contains 8 cells. The third shell thus contains 18 while the fourth contains 32 cells. Or if we consider only one hemisphere the numbers in the successive shells are 1, 4, 9 and 16."

Postulate 4. "Each of the two innermost cells can contain only one electron,[8] but each of the other cells is capable of holding two. There can be no electrons in the outside shell until all the inner shells contain their maximum numbers of electrons. In the outside shell two electrons can occupy a single shell only when all other cells contain at least one electron. We may assume that two electrons occupying the same cell are at different distances from the nucleus. Each shell, containing its full quota of electrons, thus consists of two 'layers.' We will find it convenient to refer to these layers of electrons by the symbols *I*, *IIa*, *IIb*, *IIIa*, *IIIb*, and *IVa* where the Roman numerals denote the shell containing the layer. Helium, neon, argon, krypton, or xenon, contains, respectively, the first 1, 2, 3, 4, or 5 of these layers, while niton contains all six."

These four postulates give us a definite conception of the electrons in the atoms of the inert gases. The arrangement of the cells in the different layers is seen more clearly from the following table, in which n represents the number of cells in the shell:

Layer	Radius	n	No. of cells: In axis	No. of cells: In zones
I	1	2	2	0
IIa	2	8	0	8
IIb	2	8	0	8
IIIa	3	18	2	16
IIIb	3	18	2	16
IVa	4	32	0	32

7. *J. Am. Chem. Soc.* 38, 762 (1916). This theory has also been discussed rather fully by the writer in the *General Electric Review*, 1917, pp. 403-406.

8. If, as Rydberg believes, there are two undiscovered elements of atomic weights less than that of hydrogen, then this exception in the case of the innermost cells may be avoided.

It will be observed that with this arrangement, the atom is symmetrical with respect to a polar axis passing through the nucleus and perpendicular to the equatorial plane, and since the cells all occupy equal areas in their respective shells, the atom as a whole presents four symmetrical planes passing through the polar axis and making 45 deg. angles with each other.

In attempting to arrive at the arrangement of the electrons in the outside layers of atoms other than the inert gases, Langmuir assumes three more postulates:

Postulate 5. "It is assumed that electrons contained in the same cell are nearly without effect on each other. But the electrons in the outside layer tend to line themselves up (in a radial direction) with those of the underlying shell because of a magnetic field probably always to be associated with electrons bound in atoms. (Parson's magneton theory). This attraction may be more or less counteracted by the electrostatic repulsion between the outside electrons and those in the underlying shell. The electrons in the outside layer also repel each other and thus tend to distribute themselves among the available cells so as to be as far apart as possible. The actual positions of equilibrium depend on a balance between these three sets of forces together with the attractive force exerted by the nucleus."

Postulate 6. "When the number of electrons in the outside layer is small, the magnetic attraction exerted by the electrons of the inner shells tends to predominate over the electrostatic repulsion, but when the atomic number and the number of electrons in the outside layer increase, the electrostatic forces gradually become the controlling factor. As a result when there are few electrons in the outer layer, these arrange themselves in the cells over those of the underlying shell, but where the outside layer begins to approach its full quota of electrons, the cells over the underlying electrons tend to remain empty."

Postulate 7. "The properties of the atoms are determined by the number and arrangement of electrons in the outside layer and the ease with which they are able to revert to more stable forms by giving up or taking up electrons, or by sharing their outside electrons with atoms with which they combine. The tendencies to revert to the forms represented by the atoms of the inert gases are the strongest, but there are a few other forms of high symmetry such as those corresponding to certain possible forms of nickel, palladium, erbium and platinum atoms towards which atoms have a weaker tendency to revert (by giving up electrons only)."

By means of these seven postulates it is possible to arrive at definite concepts with respect to the arrangement of the electrons in all the atoms.

The hydrogen atom contains a single electron and a nucleus of unit positive charge. The electron would on the average be situated on the polar axis of the atom. When we come to helium, the positive charge on the nucleus is two, and there are two electrons each situated at one end of the polar axis.

With lithium we begin the formation of a second shell and with each succeeding element up to neon, we add on one electron to those already present until with neon we have eight electrons situated symmetrically on the surface of a sphere and therefore resembling a cube in appearance. Thus, if we leave out of consideration the two electrons corresponding to helium, we can represent the elements from lithium to fluorine as cubes with one or more corners not filled by electrons, as shown in Fig. 3.

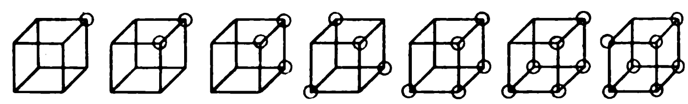

FIG. 3

Thus carbon would have two electrons in the inner shell (corresponding to the structure of helium) and four electrons on the outer ones, thus completing the six negative charges corresponding to the positive charge 6 on the nucleus. In order to account for tetrahedral symmetry of carbon, the four outer electrons are most probably situated on the four opposite corners of the cube, so that the lines joining them form a tetrahedron.

It is evident that this arrangement coupled with postulate 7 gives a very satisfactory representation of the chemical and physical properties of these elements. Thus lithium would tend to give up its single electron and revert to helium. This accounts for the high electropositive character of the element. On the other hand, fluorine may either take on an electron and thus resemble neon, or it may give up all its seven electrons to revert to helium. As the first alternative is much easier, we obtain a simple explanation of the electro-negative character of this element.

The mode of formation and properties of *LiF* are equally well accounted for. The lithium atom gives up its electron to the fluorine, leaving an atom which has a structure similar to helium with the addition of one more positive charge, while the fluorine atom in taking up the electron assumes a structure similar to that of neon, but with one less positive charge on the nucleus. Thus we form a substance which in the molten state is a good conductor of electricity; for the positively-charged helium atom (lithium ion, $\overset{+}{Li}$) will migrate towards the cathode, or negative terminal, while the fluorine atom with one extra negative charge (fluorine ion, $\overset{-}{F}$) will migrate towards the anode.

In a similar manner we can account for the formation of CH_4, NH_3, H_2O, and HF. In each case the atom of C, N, O, or F forms a system of eight by sharing the extra electrons with the hydrogen nucleus as

shown in Fig. 4 for NH_3. The white circles indicate the electrons belonging to N, while the black dots represent the electrons belonging to H. This view also accounts readily for the existence of ammonium ion as in NH_4F. (See Fig. 4) The hydrogen nucleus

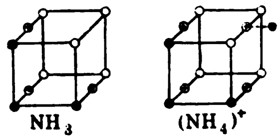

FIG. 4

belonging to the fourth H atom is shared by two of the electrons in the nitrogen atom, while the extra electron is held by relatively weak forces, just as the single electron in the case of lithium.

The elements in group *IIb* from neon to argon are quite similar to those in group *IIa*. The electrons in this layer tend to line themselves up with those of the underlying layer (see Postulate 5) and thus the elements are very similar to the corresponding elements of group *IIa*.

Beyond argon we begin the formation of a third shell. Until we reach iron the electrons arrange themselves symmetrically over the underlying electrons, so that the last mentioned atom has the structure assigned to it by Dr. Hull. That is, there are two electrons in the innermost shell and outside of this are three concentric cubes with eight electrons at the corners of each cube. In the case of cobalt and nickel the added electrons go into the polar axis, as they can no longer be arranged over underlying electrons, so that the main structure (that of the concentric cubes) remains quite similar to that of iron.

With the addition of another electron (to form the atom of Cu), the electrostatic forces of repulsion tend to overbalance the magnetic forces of attraction between electrons situated over each other and there is brought about a rearrangement of the electrons, so that the square containing the four electrons in each hemisphere tends to revolve 45 deg. about the polar axis. This arrangement, which Dr. Langmuir designates as the β-form of the Ni atom, has a higher degree of symmetry than the α-form previously considered, and thus represents the stable form towards which all the succeeding elements tend to revert (see Postulate 7). Consequently the atoms of the elements above nickel in giving up electrons tend to revert to this β-form of nickel. This is in accord with the fact that copper in the cuprous state has a valency of one, zinc has two, gallium three, etc., right up to selenium, six.

Arsenic, selenium and bromine, however, also tend to take up electrons (just as the corresponding elements N, O, and F in layer *IIa*) to form the very stable system constituting the atom of krypton.

When we come to deal with the electrons in the outer layer of shell *III* beyond krypton, we have an arrangement similar to that in layer *IIIa*, so that the elements beyond Pd tend to revert to a β-form of this element in which the electrons are situated immediately over those constituting the β-form of Ni.

With xenon the outer layer of the third shell is completed and the next series of elements is obtained by filling in successively each of the 32 cells which are present in the fourth shell. The first three or four elements beyond xenon tend to revert to the latter and thus show predominantly electro-positive character. These electrons and the successive additional ones tend to arrange themselves over the 18 of the underlying shell, "but by the time the 18 electrons have been added the electrostatic forces have begun to oppose the magnetic attraction degree. Therefore, when in tantalum an additional electron is added, the whole outside tends to rearrange itself so that the empty cells will come opposite the electrons of the underlying shell. The most symmetrical arrangement of this kind will occur when there are 18 empty cells opposite the 18 underlying electrons. The atomic number of niton in which the fourth shell is complete is 86— therefore an element having 18 empty spaces in the fourth will have an atomic number 68 corresponding to erbium. The structure of this β-form of erbium has the same kind of stability for large, nuclear charges that we found in the cases of B-nickel and B-palladium. We may therefore expect that the atoms beyond lutecium will show a marked tendency to revert to β-erbium. Thus tantalum with an atomic number 73 tends to lose five electrons and tungsten to lose six. The properties of tantalum and tungsten thus resemble those of columbium and molybdenum but because of the complexity of the atom to which they revert, and in general because of the large numbers of electrons in their outside shell, their secondary valence forces are more highly developed."

A remarkable feature of this point of view is the manner in which it accounts for the existence of the so-called "rare earth" elements beginning with cerium and ending with lutecium (*Lu*). These are shown enclosed in the dark lines in Fig. 1. They are all chemically similar in properties and show no characteristic valency, so that it has been apparently impossible to group them with any other elements.

The present theory, however, would lead to the conclusion that after the third or fourth electron is added in the fourth shell, the succeeding elements would exhibit just this kind of resemblance and lack of definite valency. Furthermore, this family resemblance ought to cease with the addition of the eighteenth electron, which as a matter of fact corresponds to lutecium, and this marks definitely the last of the rare earths.

From the point of view of this theory, the rare earth group of elements is just a repetition on a larger scale of a similar interesting fact observed in the case

of the elements *Ti, V, Cr, Mn, Fe, Co, Ni* and *Cu* whose electrons are situated in layer *IIIa*. All these elements show more or less similar chemical properties and lack of characteristic valency.

"The β-form of the erbium atom contains 18 empty cells arranged over the 18 cells of the third shell. When electrons are added as we pass to elements of large atomic number, the first eight of them naturally tend to arrange themselves at the corners of a cube, because of the magnetic attraction of the eight electrons in the second shell. The next two electrons for reasons of symmetry then arrange themselves in the polar axis. We thus have the three eight group elements osmium, iridium and platinum.

"The next elements gold, mercury, etc., are distinctly diamagnetic. The same sharp break occurs here as we found between nickel and copper, palladium and silver, lutecium and tantalum, although its magnitude is much less. We may therefore assume that beyond platinum the electrons tend to rearrange themselves in a β-form in which the ten electrons that have been added since erbium endeavor to get farther away from those of the underlying electrons. The eight empty cells tend to take symmetrical positions in the atom probably at corners of a cube, and the cells containing electrons, space themselves as best they can. The fact that an arrangement of this kind does not have nearly the symmetry which we found for the β-form of the nickel atom is probably the explanation of the fact that the tendency of the succeeding elements to revert to this β-form of platinum is much less marked than we observed in the cases of reversion to nickel, palladium and erbium. Thus we find that gold and mercury have variable valence differing in this respect from silver and cadmium. Thallium forms univalent and tervalent ions whereas indium forms only tervalent. Lead only exceptionally is quadrivalent, while this seems to be normal condition of tin compounds. Thus stannous salts are strong reducing agents, but divalent lead salts are not. Bismuth is normally tervalent and forms only a few very unstable compounds in which it is quinquivalent. Antimony on the other hand has about equal tendencies to be tervalent or quinquivalent.

"With niton the first layer of electrons in the fourth shell is completed. As we add more electrons we should expect to go through the same cycle as that of the rare earth period. The properties of the first two or three elements are determined primarily by the ease with which they give up electrons. Thus radium very closely resembles barium, differing from it in chemical properties only by its slightly greater secondary valence which manifests itself here by slightly decreased solubility of its salts.

"Thorium resembles cerium and zirconium, the elements of similar constitution."

The last shell of electrons beginning with niton (atomic number 86) is incomplete. This must be due to increasing instability of the nucleus, as is shown by the fact that the elements beyond thallium exhibit the phenomena of nuclear disintegration.

Langmuir shows that by means of this theory of atomic structure it is possible to explain not only the periodic properties of all the elements, but also the magnetic properties, and a large number of the so-called physical properties such as boiling points, freezing points, electrical conductivity, etc.

Mention has already been made of the manner in which the theory can be applied to explain the mode of formation and properties of some of the simpler chemical compounds. As well known, the ordinary theory of valence which has been found so useful in accounting for the formation of just these kinds of simple compounds, is found to be inapplicable in a large number of cases, notably those of inorganic compounds. Langmuir's theory, however, leads to a simple theory of valence which applies equally well to all kinds of compounds. This theory, which may be designated as the theory of octets, is based upon the following simple equation:

$$e = 8n - 2p,$$

where e is the total number of electrons available in the outer shells of all the atoms in a molecule; n is the number of octets forming all outside shells, and p is the number of pairs of electrons held in common by the octets.

On this basis, the single bond of the ordinay theory is replaced by a pair of electrons. Thus, in the case of CO_2, if we place $n = 3$, $e = 4 + 2 \times 6$, and solve for p, we find that four pairs of electrons must be held in common, and the molecule must therefore be represented by some such structure as that shown in Fig. 5.

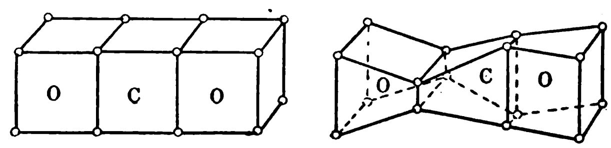

FIG. 5

According to the classical theory we would assign four bonds to the carbon atom so as to satisfy the two bonds belonging to each of the oxygen atoms. Similarly two atoms of fluorine would combine, according to the octet theory, to form a molecule, F_2, by sharing one pair of electrons. In his paper Langmuir shows how the theory can be applied to explain the mode of formation of different compounds of *N, P, S*, and other elements for which the ordinary theory is entirely inadequate.

An interesting theory is suggested of the structure of the molecules of N_2, CO, HCN, and NO. In these four cases it is assumed that the kernels of both atoms in the molecule are contained within a *single octet*. Thus of the 14 electrons available in two atoms of nitrogen or in the atoms of carbon and oxygen, eight

form an octet and contain inside this octet the other six, together with the corresponding kernels. "This accounts for the practically identical physical properties of nitrogen and carbon monoxide and for the abnormal inertness of molecular nitrogen."

Conclusion

There is no doubt that Langmuir's theory of atomic structure has proved extremely successful from the chemist's point of view. That its conclusions are apparently at variance with Bohr's theory, may prove in the near future to be not quite as much the case as it looks at present. It must be observed that all of Langmuir's conclusions would be just as valid if we assume that the electrons are not actually stationary, but rotating or vibrating about mean positions which are located at the points in the atom corresponding to the centers of Langmuir's electronic cells. As stated by Langmuir, "Bohr's stationary states have a rather close resemblance to the cellular structure postulated in the present theory. There are also striking points of similarity with J. J. Thomson's theory of the structure of atoms, in which he assumes that the attractive forces are limited to certain tubes of force. It is probable, however, that the cellular structure is not so much a property of space as of the electron. It seems that the electron must be regarded as a complex structure which undergoes a series of discontinuous changes while it is being bound by the kernel or nucleus of an atom. There seems to be strong evidence that an electron can exert magnetic attractions on other electrons in the atom even when not revolving about the nucleus of the atom."

It is quite probable that a complete theory of atomic structure will not only reconcile the chemical properties of the atom with the fundamental truth enunciated in Bohr's derivation of the Rydberg constant, but also will, at the same time, give us a physical concept of the quantum theory which we lack at present.

ELECTRON TUBE GENERATORS

The determination of the output characteristics of electron tube generators is the subject of Scientific Paper No. 355 of the Bureau of Standards. The paper points out that owing to saturation and rectification effects in three-electrode vacuum tubes, the currents which they deliver to any type of output circuit, when used as a generator, are heavily loaded with harmonics. Experimental results indicate that the frequency of the oscillating currents generated is the natural frequency of the output circuit. Hence this circuit behaves as a filter in series with the tube and the d-c. power system, and the useful output current is approximately sinusoidal, whatever the distortion of the tube currents, depending in amplitude solely upon the fundamental constituents of the tube currents.

General expressions are derived for the power and current output in terms of static characteristics of the generating tube, and are corroborated by experimental results obtained with a particular tube.

Copies of the paper may be obtained by addressing a request to the Bureau of Standards, Washington, D.C.

APPRECIATION

The following excerpts are taken from some of the many letters of appreciation which have recently been received by the Secretary and the Editor in regard to the new Journal of the A. I. E. E.:

I just want to add a personal word and a word to the officers expressing my pleasure at the publication of the new Journal of American Institute of Electrical Engineers. It seems to me to be a remarkably creditable publication, and I hope that you will not have too great difficulty in the future living up to the standard which has been set.

F. B. Jewett, New York.

The first copy of your new Journal arrived on my desk this morning and I wish to offer my hearty congratulations to you on the splendid publication which you have produced. It is a credit to yourself and to the Institute and I trust that the change you have inaugurated will be of great benefit to the Institute.

Fraser S. Keith, Montreal, Can.

I take this occasion to congratulate you upon the excellent appearance of your January Journal, and upon the significance of the new policy which its appearance represents.

W. F. M. Goss, New York.

I want to take this opportunity to congratulate you upon the Journal, of which the Institute has just issued its first copy. It is a splendid piece of work, and reflects credit on all who had anything to do with it.

Fred'k C. Bates, New York.

I wish to express my appreciation of the quality of the material in the first issue of the Journal of the American Institute of Electrical Engineers. If this excellence is maintained, I predict that the Journal will become the most valued of any publication in the electrical field. The articles are all practical and are written within the comprehension of the average reader.

D. E. Carpenter, Scranton, Pa.

The new form of the Journal pleases me very much, and I wish to express to you my appreciation of the new publication. Surely it has made a splendid beginning, and I look forward to enjoying the coming issues immensely.

Good luck to the Journal, and more power to your elbow!

C. H. Sanborn, Allston, Mass.

Permit me to congratulate you and your editor, Mr. Metcalfe, upon the very pleasing appearance of the Journal of the American Institute of Electrical Engineers in its new form.

Alfred D. Flynn, New York.

I want to congratulate you on the splendid appearance of the January issue of your Journal. It is certainly a credit to any association. I was particularly interested in the lower half of page 5 of the advertising section.

Rodman Gilder, New York.

Essential Statistics for General Comparison of Steam Power Plant Performance

BY W. S. GORSUCH

Engineer, Economics, Interborough Rapid Transit Co., New York, N. Y.

This paper briefly outlines a method for preparing statistical reports relating to power generation in steam power plants, whereby fairly close comparisons can be made of the efficiencies between different plants, without going into a detailed study of the thermal characteristics of the plants, or the intricate subject of power costs.

The essential items of steam power plant performance that should be recorded and a uniform method of expressing them, are given in tabular form, followed by an illustration demonstrating the advantage of the proposed method.

THE principal difficulty with operating statistics of steam power plants as published today by various State and Governmental bodies is that they are wholly inadequate for the purpose of determining the efficiency of a plant or making general comparisons between different plants. In practically every case the bare figure of coal consumption per kilowatt-hour is given without any reference whatever to the quality of coal and without a clear understanding as to the character of the load on the station. When load factors are given, the figures are often misleading because they are computed upon different bases. No uniformity exists in reporting the output of the power plant, the gross output being used in some cases and the net output in others. Because of these facts the reports as at present published are limited in their use, principally serving to show the total amount of power generated and the total quantity of coal consumed.

The object of this paper is to point out the essential items of steam power plant performance which should be recorded in statistical reports, and to suggest a uniform method of expressing them for the purpose of making a general comparison between different plants, without going into an analysis of the thermal characteristics or cost of generation.

It must be conceded that the proper criterion for comparing power plants is the commercial efficiency, that is, the total cost per kilowatt-hour sent out from the a-c. power station bus, which is the ultimate test of design and operation. To make such a comparison, a uniform system of accounting would have to be adopted, and suitable correction factors would have to be established whereby the operating results and conditions can be reduced to a more or less common basis, all of which is beyond the scope of general statistical reports. For this reason, the discussion of costs in this paper will be limited to that of coal which is the largest single item in the cost of generation.

What is said here refers particularly to steam power plants using coal as fuel and in which all the output is in the form of electrical energy, but the principles relate in their broad application to steam power plants using fuel other than coal and where both steam and electrical energy are supplied.

For the purpose of obtaining a better knowledge of what a plant is doing and for judging the relative merits of different plants, it is recommended that the following items be recorded in statistical reports relating to power generation in steam power plants, and that they be expressed in a uniform way as indicated. These items reflect the influence of station design and arrangement of apparatus, method of operation and management, load, quality and kind of fuel used, and at the same time indicate the character of the load imposed upon the station. For convenience the items are divided into two groups, coal characteristics and load characteristics.

I. *Coal Characteristics of the Plant*
- (1) Average B.t.u. supplied to plant per kw-hr. net output.
- (2) Thermal efficiency of plant in per cent.
- (3) Average B.t.u. per dollar, coal as received (moist basis).
- (4) Coal factor or pounds of coal per kw-hr. net output (moist basis).
- (5) Average B.t.u. per pound of coal as received (moist basis).
- (6) Cost of coal per ton (2240 pound) delivered alongside the plant.
- (7) Kind and character of coal.
- (8) Cost of coal in cents per kw-hr. net output.

II. *Load Characteristics of the Plant*
- (9) Average daily load factor of load
- (10) Maximum load for the year.
- (11) Yearly load factor of load.

  (Items 9–11:) Interval of maximum load 15 minutes or 1 hour depending upon character of load.
- (12) Kilowatt-hours net output for the year—(kilowatt-hours sent out from the a-c. bus).
- (13) Installed rated capacity, that is, the aggregate maximum continuous rating of the generators in kilowatts.
- (14) Average kilowatt-hours net output per kilowatt installed rated capacity.

Items 1, 2, 3, 8, 11 and 14 can readily be computed from items 4, 5, 6, 10, 12 and 13.

Coal Characteristics. The fundamental basis of determining and comparing steam power plant efficiencies as to coal consumption should be the average B.t.u. supplied per kilowatt-hour net output at the power station bus. This will give a basis for discussing and comparing plant efficiencies upon which there can be no misunderstanding. With this factor and a knowledge of the character of load, we have a very good criterion by which to judge the merits of a plant both as to design and operation. The average B.t.u.

To be presented at the Midwinter Convention of the A. I. E. E., New York, February 18, 1920.

supplied to the plant per kilowatt-hour net output for the year is determined by dividing the kilowatt-hour net output for the year into the product of the total pounds of coal used during the year by the average B.t.u. per pound of coal as received, (moist basis). This measure of efficiency can be expressed in thermal efficiency or what is generally termed over-all plant efficiency, by dividing it into 3415.

Before a very close comparison can be made between two plants each of which uses a different grade of coal, the coal characteristics of both plants will have to be placed on the basis of coal having the same quality. This involves the effect of quality of coal on the boiler capacity and efficiency which must be taken into account if the object sought is to make an analysis of the thermal characteristics of the plants. However, since the purpose of this paper is to deal with general comparisons which can be made from statistical records without going into a detailed study of the plants, it is proposed to make fairly close comparisons which correct for the difference in the B.t.u. value of the coal itself, but which neglect the effect on the boiler capacity and efficiency. Notwithstanding this inaccuracy which will be relatively small, even with a large difference in the quality of coal, the comparisons as outlined are much more useful than any that can possibly be made from the statistical information published today.

Two plants can be directly compared as outlined above on the basis of the average B.t.u. supplied per kilowatt-hour net output, because both the coal factor and quality of coal are taken into account. A comparison however, cannot be made between the coal factors as given without first correcting for the difference in the B.t.u. value of the coal used. This can be done by multiplying the coal factor of either plant by the ratio of the B.t.u. value of the coal used by that plant, to the B.t.u. value of the coal used by the other plant, thus placing the coal factors on the same basis in so far as the B.t.u. value of the coal itself is concerned.

Because of the lack of laboratory facilities it may not be possible for some small plants to determine the average B.t.u. value of all the coal consumed during the year. In such cases the results of periodic tests should be recorded with an explanatory foot-note, as they will serve to give a general idea of the conditions under which the plant is being operated. There is nothing that upsets the boiler room force so much as changing the grade of coal without notice, since every change necessitates a readjustment of methods of firing. With a knowledge of just what kind of coal is being supplied, the cause of the change in efficiency can more readily be traced.

Generally speaking, the highest thermal efficiency is obtained when burning the highest quality of coal. On the other hand, a low grade of coal purchased at a low price may result in a better commercial efficiency. The B.t.u. per kilowatt-hour net output together with the B.t.u. per dollar will, therefore, give an index of the commercial efficiency of the plant, since coal is by far the largest item in the cost of power production.

Where mixed fuel is used, the relative amount of anthracite and bituminous coal should be recorded, together with the average B.t.u. value of each.

Load Characteristics. The character of load carried has a marked influence on plant efficiency, a fluctuating load and a load with sharp peaks and low load factor require more coal than an equally steady load or a load with a high load factor. In comparing plant performance therefore, it is essential to know the load conditions. These are best indicated by the ratio of the average load to the maximum load for the same period, which is known as the load factor of load and is usually expressed in percentage. Industrial and railway loads are less affected by seasons and daily weather conditions than lighting loads. For this reason it is recommended that the interval for the maximum load be fifteen (15) minutes for stations supplying an appreciable lighting load, and one (1) hour for all other stations.

Much confusion is caused throughout the electrical industry, due to the fact that a uniform method has not been used in determining the load factor. For the purpose of comparing the load conditions of various generating stations, the daily load factor seems to be most suited, and it should be the ratio of average net output during 24 hours to the net maximum load, multiplied by 100 to express in percentage. The load factor should be computed on the basis of 24 hours for the reason that it represents the relation between the actual and possible hours use of the maximum load. In comparing power station statistics which are usually on a yearly basis, the average daily load factor should be used because it is more representative of the operating conditions in the plant itself than a load factor based on the maximum of the month or year.

The fundamental basis of determining and comparing those items of power plant performance that are expressed in terms of unit output of the plant, should be the kilowatt-hour net output. This will eliminate any difference in power consumption of auxiliaries or power used for other purposes in the plant. The result will be that all the factors will be on the basis of the character of load imposed upon the plant.

The plant factor which is the ratio of the average hourly load for the year to the rated capacity of the plant is a measure of the utilization of the installed capacity. This is obtained by dividing 8760 into Item 14.

For the purpose of illustrating the advantage of the proposed over the present method for preparing statistical reports relating to power generation in steam power plants, the following comparison is made between a few of the items of two plants, A and B, which have similar load characteristics, but which use coal differing in quality and price.

	Plant A	Plant B
I. *Coal Characteristics of the Plant*		
1. Average B.t.u. supplied to plant per kw-hr. net output	22,400	25,600
2. Thermal efficiency of plant in per cent	15.24	13.34
3. Average B.t.u. per dollar, coal as received (moist basis)	5,226,666	5,734,400
4. Coal factor, or pounds of coal per kw-hr. net output (moist basis)	1.60	2.00
5. Average B.t.u. per pound coal, as received (moist basis)	14,000	12,800
6. Cost of coal per ton (2240 lb.) delivered alongside plant	6.00	5.00
7. Kind of coal	Bituminous	Bituminous
8. Cost of coal in cents per kw-hr. net output	0.428	0.446
II. *Load Characteristics of the Plant*		
9. Average daily load factor of load. } Interval of maximum load one hour	50	54
10. Maximum load for the year. } Interval of maximum load one hour	90,000	80,000
11. Yearly load factor of load. } Interval of maximum load one hour	40	38
12. Kw-hr. net output for the year.—(kw-hr. sent out from the a-c. bus)	315,460,000	217,248,000
13. Installed rated capacity, that is, the aggregate maximum continuous rating of the generators in kw	125,000	100,000
14. Average kw-hr. net output per kw. installed rated capacity	2,525	2,173

A comparison of Items 1 and 2 shows that on the basis of plant *A*, plant *B* has a 12.5 per cent lower plant efficiency and requires 14 per cent more B.t.u. per kilowatt-hour net output at the station bus. If the effect on boiler capacity and efficiency due to quality of coal are neglected, the lower efficiency for plant *B* can be attributed principally to a difference either in station design or method of operation or both since the load characteristics are practically the same.

The equivalent coal factor of plant *B* based on coal having 14,000 B.t.u. per pound, is 1.83 pound or 0.23 pounds more per kw-hr. net output than that required for plant *A*. This means that for the same output and with coal having the same B.t.u. value, plant *B* consumes approximately 14 per cent more coal than plant *A*.

With the present method of recording power plant statistics, Item 4 showing the coal factors would be given, but Items 1, 2, 3, and 5 would not. In this case it would be impossible to tell whether or not any part of the difference in the coal factors was due to the quality of coal. If the relative merits of the two plants were judged from the coal factors alone, the comparison would be misleading for the reason that while the coal factor for plant "*B*" is 25 per cent higher than that for plant "*A*", the B.t.u. supplied per kw-hr. net output is only 14 per cent higher. This very clearly brings out the fact that a general comparison cannot be made between the coal factors of two plants without a knowledge of the relative B.t.u. value of the coals used.

Other interesting comparisons can be made from the above tabulations, one of which is the cost of coal per unit of output. The figures given in item 8 show that the cost of coal per kw-hr. net output for plant "*B*" is approximately 4.2 per cent higher than that for plant "*A*".

The above discussion demonstrates the need of a uniform standard method of recording the fundamental factors of steam power station performance in statistical reports, and this paper is presented with the hope that some action will be taken to adopt such a method.

RECENT PROGRESS OF ELECTRIC PROPULSION IN U. S. NAVY

The Navy has recently announced the award of a number of new contracts for electrical machinery to propel the new Battle Cruisers and Battle Ships.

The Battle Cruisers are to have a displacement of about 44,000 tons, a maximum speed of 34 knots and fractional speeds at which the economy will be very good. To achieve this high speed will require about 180,000 horse power per ship. This power will be derived from four large steam turbines, each driving a 40,000. kv-a. three-phase, 5000-volt generator at 1835 rev. per min. There will be four propeller shafts on each of which will be mounted two three-phase induction motors of 23,000 h.p., each having 22 poles and running at 331 rev. per min. These motors are designed to operate also with 44 poles giving 6800 h.p. at 170 rev. per min., the condition for half speed.

The new Battle Ships are larger than the New Mexico, being designed for a displacment of 43,000 tons and require 60,000 h.p. to drive them at their contract speed of 23 knots. The power for the battle ships will be derived from two turbine-driven electric generators rated as 22,000 kv-a., two-phase, 5000 volts, 1800 rev. per min. There will be one induction motor on each of the four propeller shafts, each motor rated as 15,000 h.p. at 225 rev. per min. with 16 poles. For fractional speed running the motors will be arranged with 24 poles giving 3600 h.p. at 150 rev. per min.

The contracts for the power plants for these ships have been awarded to the General Electric and the Westinghouse companies respectively.

The Bureau of Census states that according to a report about to be issued showing results of census of telephones covering the year 1919, there are 53,234 separate telephone systems and lines. These lines and systems operated 28,827,188 miles of wire in United States, and connected 11,716,520 telephones and 21,175 public exchanges. Messages sent over these wires aggregated total of nearly 22,000,000,000.

Inherent Regulation of Continuous Current Circuits

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This paper discusses the voltage changes, inherent in d-c. circuits, upon change of load. These variations are independent of i r drops or speed of prime movers. A simple means of mitigating their effect is given.

Introduction

IN developing a device to measure time to one millionth of a second we were at one time confronted with the question, how is the voltage of a "flat" compounded generator affected by an increase or decrease of load? We were not interested in what happened as indicated by a voltmeter, (as the generator was carefully compounded for the range of load under consideration), but what happened at the instant the load was changed. We were surprised at the extent of the voltage drop, indicated by the oscillograph, when the load was increased. The very interesting oscillograms and data resulting from further investigation of this drop form the basis of this paper.

The principles governing this drop are set forth in elementary text books on engineering, and while simple in this form their application to a network of conductors supplied with current by a generator is difficult to follow, and when mathematically stated lead to very complex equations that can be comprehended only by a painstaking study of the problem.

The result is that the busy engineer with insufficient time to concentrate upon this subject frequently encounters, in practise, manifestations of this drop without realizing the cause or recognizing the principle.

We find very little written on the subject; a suggestion of it here and there in articles referring to transients, and with the exception of reference made to it in Lamme's paper[1] on commutation, no comprehensive statement of the case has come to our notice.

The simple explanation of this dip in voltage given in Lamme's paper follows verbatum: "Assume, for instance, a 100-volt generator supplying a load of 100 amperes—that is, with one ohm resistance in circuit. The drop across the resistance is, of course, 100 volts. Now, assume that a resistance of one ohm is thrown in parallel across the circuit. The resultant resistance in circuit is then one-half ohm. However, at the *first instant* of closing the circuit through the second resistance, the total current in the circuit is only 100 amperes, and therefore the line voltage at the first instant momentarily must drop to 50 volts. However, the e. m. f. generated in the machine is 100 volts, and the discrepancy of 50 volts between the generated and the line volts results in a very rapid rise in the generator current to 200 amperes. If the current rise could be instantaneous, the voltage dip would be represented diagrammatically by a line only; that is, no time element would be involved. However, *the current cannot rise instantaneously in any machine*, due to its self-induction, and therefore, the voltage dip is not of zero duration, but has a more or less time interval. The current rises according to an exponential law, which could be calculated for any given machine if all the necessary constants were known. However, such a great number of conditions enter into this that it is usually impracticable to predetermine the rate of current rise in designing a machine; and it would not change the fundamental conditions if the rate could be predetermined, as will be shown later."

Lamme points out that, "If a given load is thrown on a machine, the dips will be relatively less the higher the load the machine is carrying. Also, if the *same percentage* of load is thrown on each time, then the dips should be practically the same, regardless of the load the machine is already carrying." He also gives a table of test results to substantiate this taken from oscillograph curves which were considered too faint to be reproduced in the paper.

In our investigation of the "dip" we were able to get very good oscillograms though the phenomenon is a difficult one for the oscillograph to record. It is the purpose of this paper to extend the evidence by oscillograph records and plots drawn up from a mathematical consideration of a range of ideal circuits, which give at a glance a better understanding of the relative importance of various conditions than would be disclosed in pondering over a word picture.

Load Increments

Several types of generators were examined and the "dip" found in all in accordance with the theory within the limitations of the oscillograph.

The following oscillograms were obtained from the same generator under various conditions of load and may be considered to represent fairly the performance of any continuous-current generator, making due allowance for generator constants.

The performance of any continuous-current generator in this regard can be more easily understood by considering what happens when

A non-inductive load is added to a generator carrying no load........................(Case one);

An inductive load is added to a generator carrying no load........................(Case two);

To be presented at the 8th Midwinter Convention of the A. I. E. E., New York, February 19, 1920.

1. B. G. Lamme, "Physical Limitations in D-C. Commutating Machinery." TRANS. A. I. E. E. 1915, Part II.

A non-inductive load is added to a generator carrying a non-inductive load.............(Case three);
An inductive load is added to a generator carrying a non-inductive load..............(Case four);
A non-inductive load is added to a generator carrying an inductive load..................(Case five);
An inductive load is added to a generator carrying an inductive load..................(Case six).

CASE ONE

If an ideal non-inductive resistance is thrown on the circuit of a separately excited generator carrying no load, there will be an instant demand for current of value $\frac{E}{r_1}$ where E is the voltage at the terminals to which load is applied and r_1 is the resistance of the applied load.

Owing to the inductance of armature and leads, current cannot be supplied instantly, and as no current was flowing before load was applied and did flow afterward, obviously it must have increased from zero value. As $E = IR$ the voltage must drop to zero at the instant the load is applied, and increase along a simple exponential curve depending only upon the time constant of the circuit, to the value equal to the generated voltage minus the internal IR drop.

The drop to zero is therefore, fundamental and is independent of the type of the generator, its size, its generated voltage, or the value of the applied load. These variables influence only the time of recovery to normal voltage and the form of the recovery curve.

Considering the inductance of the circuit to be confined to the armature: The instant demand for current gives rise to an e. m. f. of self-induction which opposes any increase of current (at that instant zero) and with respect to the generated voltage is therefore a counter e. m. f. The value of this counter e. m. f. with respect to the value of the generated voltage at any instant during the transient, is just sufficient to allow current to flow into the circuit at a rate such that the e. m. f. of self-induction ($L \frac{di}{dt}$) at any instant added to the IR drop at that instant equals the generated voltage. Therefore, at the instant when load was applied and the current was zero the counter e.m.f. of self-induction just equaled the generated voltage in value, consequently the voltage of the circuit reduces to zero.

If, as in all practical cases, part of the inductance is in the leads of the external circuit, the voltage at the generator terminals should drop instantaneously to a value approaching zero as the inductance of the external circuit approaches zero.

Capacity effects greatly complicate matters and their consideration precludes a simple presentation of the phenomena. This is particularly so in the case of underground cable distribution where we find distributed capacity and inductance to a considerable extent. However, in the case of isolated plants, overhead distribution, and branches of underground systems shut off, as it were, by the inductance of protection devices, instruments, meters, etc., the available capacity is, in general, so small as compared to the instant demand for energy that capacity effects have been neglected. Those who wish to consider capacity effects in connection with this phenomenon can refer to such standard works as "Transient Phenomena" by C. P. Steinmetz, and "Propagation of Electric Waves Along Telegraph Conductors" by J. A. Fleming.

The following conclusions and equations assume lumped constants that remain constant during the time necessary for the readjustments to take place, and are applicable also to battery circuits where there is a series inductance that would correspond to the inductance of the generator armature, as for instance, the series coils of a circuit breaker or watt-hour meter.

As previously pointed out, applying a non-inductive load to an unloaded generator results, at the generator terminals, in an instantaneous drop of voltage to zero. From this point the voltage returns to normal value according to an exponential curve.

$$e = E\,(1 - \epsilon^{-\alpha_1 t}) \qquad (1)$$

where

e is voltage at any instant
E = normal voltage
t = time since application of load.

$$\alpha_1 = \frac{r}{L_a}$$

where

r = complete resistance of circuit.
L_a = inductance of armature.

Equation **1** can be developed from

$$e = i r_1 \qquad (2)$$

where i is instantaneous value of current
r_1 = resistance of applied load.
and

$$i = I\,(1 - \epsilon^{-\alpha_1 t}) \qquad (3)$$

where $$I = \frac{E}{r_1}$$

At $t = 0$, that is at the instant of closing the switch $\epsilon^{-\alpha t}$ reduces to 1, and equation **3** becomes

$$i_{(t=o)} = 0 \qquad (4)$$

which substituted in (**2**) reduces (**2**) to

$$e_{(t=o)} = 0$$

From the foregoing it will be seen that the voltage drop is independent of the value of the resistance applied, also that the velocity of return to normal is a function of the resistance, and an inverse function of the inductance.

The natural question as to the whereabouts of the voltage generated by the rotating armature of the

machine, which is dependent only upon the speed of rotation and the strength of field, can be answered by a study of the reactions of the armature itself, the instant of closing the circuit.

Because the armature is inductive it resists any attempt to change the value of current flowing in it by a counter e. m. f. $= e_c$

$$e_c = L_a \frac{di}{dt} \tag{5}$$

which by differentiating (3) with respect to t, and substituting in (5) becomes

$$e_c = rI\,\epsilon^{-\alpha_1 t} \tag{6}$$

$$= E\,\epsilon^{-\alpha_1 t} \tag{7}$$

which at $t = o$ becomes

$$e_{c\,t=o} = E$$

From **7, 3,** and **2** it is seen that the sum of the external ir_1 voltage and the armature reactance voltage neglecting armature resistance, is always equal to the generated voltage, that is

$$ir_1 + L_a \frac{di}{dt} = E$$

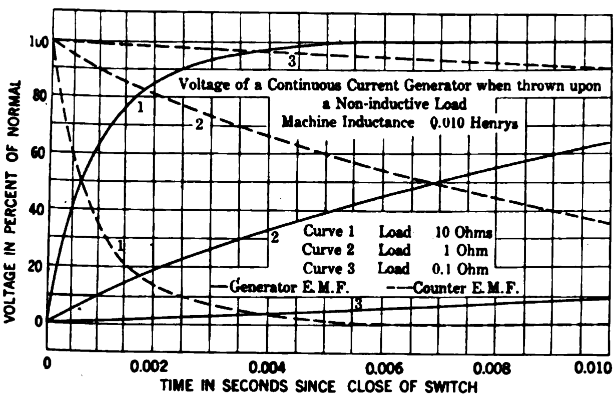


Fig. 1

Fig. 1 is a plot from calculated values and illustrates how a change in the value of the applied non-inductive load affects the shape of the voltage recovery curve and the time of recovery. The solid lines represent current increase as well as generator e. m. f. The broken lines represent the decrease in counter e. m. f. as the current approaches its steady value. The sum of the generator voltage and the counter e. m. f. at any instant during the transient equals 100 per cent of the generator voltage when the transient terminates.

Some oscillograms from actual tests are shown in Fig. 2. None of these show the voltage drop completely to zero, as should be expected, for a simple calculation is sufficient to show that in every case, the rate of rise of voltage was such that, assuming a natural period of 4000 cycles per second for the oscillograph vibrator, the voltage would be sufficiently great to give measurable deflections before the vibrator could return to zero. The table of test results given in Lamme's paper, taken from oscillograph curves, does not indicate sufficient drop in cases where the added load was a large part of the combined load, particularly where a load of 417 amperes was added to a 1200-volt generator carrying no load. The volt "dip" from 1200 to 500, there recorded, we believe due to the limitations

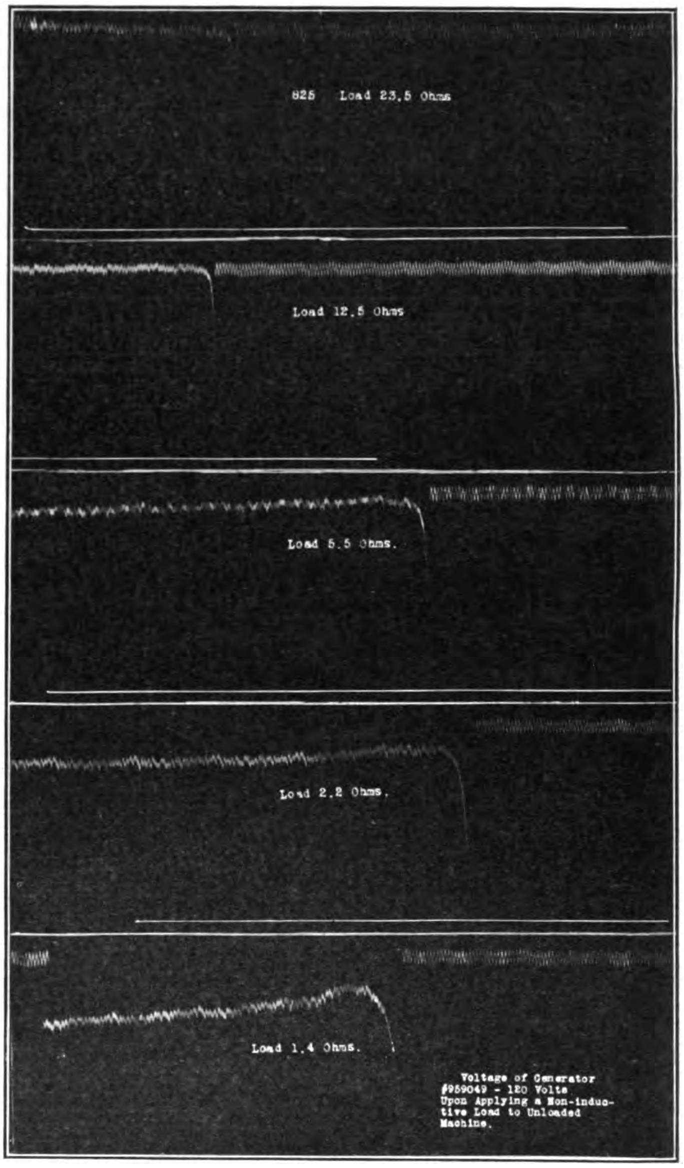


Fig. 2

of the oscillograph (mentioned by Lamme), should have been substantially to zero volts.

The oscillograms show clearly the variation in the rate of recovery and time of recovery with varying demand upon the generator. The distance between each peak represents an elapsed time of approximately 0.001 second. Some of the detail in the original oscillograms has disappeared due to the several photographic processes necessary to reduce them to print. None have been retouched for any purpose.

Case Two

An inductive load thrown upon an unloaded machine.

Under these conditions the voltage can never drop to zero, since

$$e = ir + \frac{di}{dt} L_1 \qquad \textbf{(9)}$$

where L_1 is inductance of load.

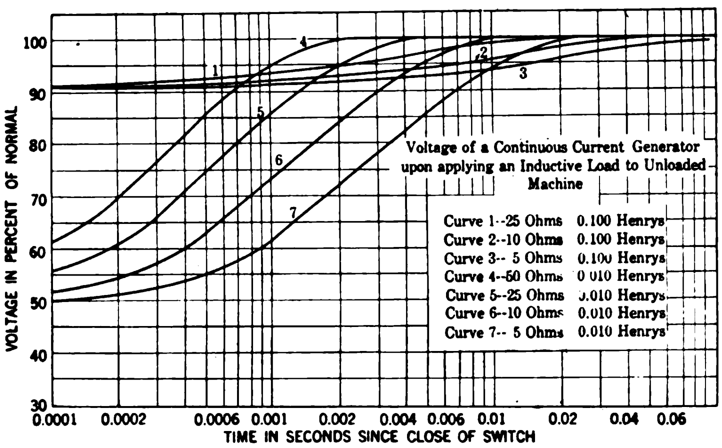


Fig. 3

As in equation (**3**) the current will rise according to an exponential law,

$$i = I(1 - \epsilon^{-\alpha_2 t}) \qquad \textbf{(10)}$$

where
$$\alpha_2 = \frac{r_1}{L_a + L_1}$$

differentiating we get

$$\frac{di}{dt} = \frac{r_1 I}{L_a + L_1} \epsilon^{-\alpha_2 t} \qquad \textbf{(11)}$$

$$= \frac{E}{L_a + L_1} \epsilon^{-\alpha_2 t} \qquad \textbf{(12)}$$

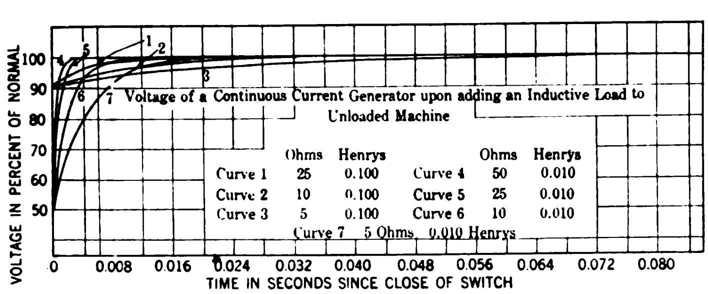


Fig. 4

substituting (**10**) and (**12**) in **9** we get

$$e = E(1 - \epsilon^{\alpha_2 t}) + \frac{L_1 E}{L_a + L_1} \epsilon^{-\alpha_2 t} \qquad \textbf{(13)}$$

which at $t = o$ becomes

$$e_{t=o} = \frac{L_1}{L_a + L_1} E \qquad \textbf{(14)}$$

That is, at the instant of closing the circuit the voltage of the machine divides in the ratio of the inductance of the external and internal circuits, and there is an instantaneous drop to this value. The instantaneous voltage drop depends upon the ratio of the inductances, and is independent of their absolute value, or of the resistance of the circuit. The velocity of return to normal voltage, however, depends, upon the resistance, since at the instant of closing the switch

$$\frac{dt}{dt} = \frac{rI}{L_t}$$

where
$$L_t = L_a + L_1 \qquad \textbf{(15)}$$

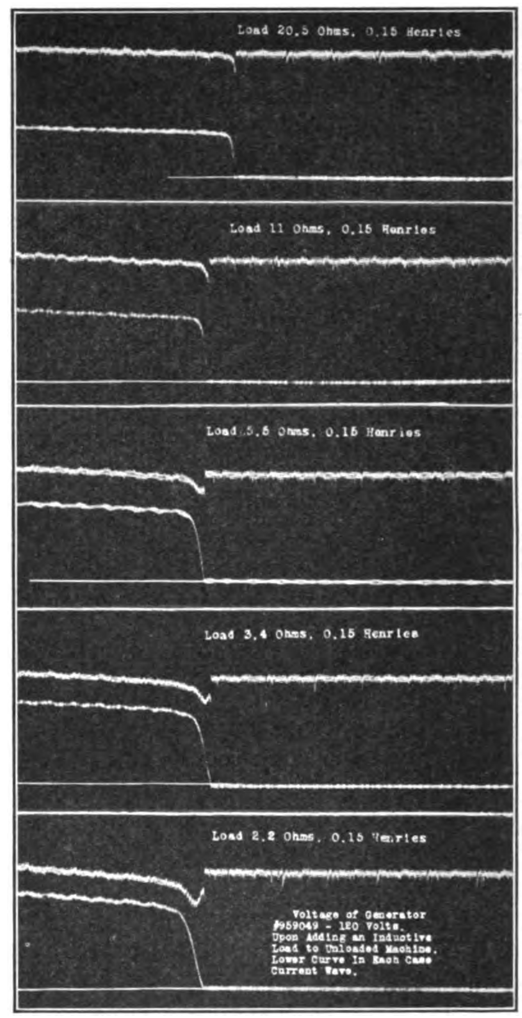


Fig. 5

Fig. 3 is a plot of calculated values on semilogarithmic paper and shows how a change in the value of resistance and inductance of applied load affects the extent of voltage drop and the rate of rise to normal.

Fig. 4 gives the same data plotted on cross section paper.

Oscillograms from tests under several conditions of load are shown in Fig. 5.

Case Three

A non-inductive load added to a machine carrying a non-inductive load.

In this case there is an instantaneous drop of voltage to a value that is equal to the combined resistance of

the circuits, times the current furnished by the machine at the instant of closing the switch,—that is

$$e_{t=o} = \frac{I_1 (r_1 + r_2)}{r_1 r_2} \tag{16}$$

where

r_1 = steady load.
r_2 = added load.

$$I_1 = \frac{E}{r_1}$$

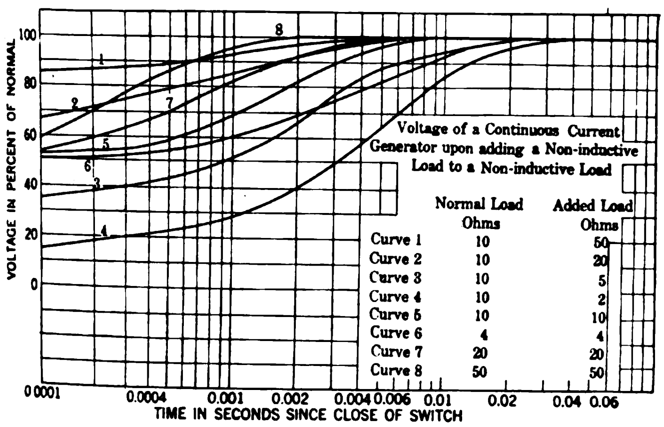


FIG. 6

The current builds up along an exponential law.

$$i = I_1 + I_2 (1 - \epsilon^{-\alpha_3 t}) \tag{17}$$

where

$$I_2 = \frac{E}{r_2}$$

$$\alpha_3 = \frac{(r_1 + r_2)}{r_1 r_2 L_a}$$

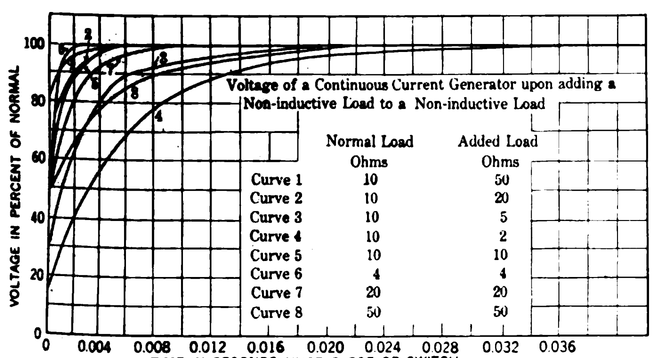


FIG. 7

and the voltage is

$$e = iR \tag{18}$$

where

$$R = \frac{r_1 + r_2}{r_1 r_2}$$

$$e = I_1 R + R I_2 (1 - \epsilon^{-\alpha_3 t}) \tag{19}$$

Fig. 6 is a plot of calculated values to logarithmic abscissas for several values of steady load and added load.

Fig. 7 gives the same data plotted to rectilinear coordinates.

Oscillograms from tests under several conditions of load are shown in Fig. 8.

Oscillograms for similar values of load added to a generator under no load (case one) are shown for comparison.

CASE FOUR

The machine carrying a non-inductive load, and an inductive load added.

In this case there is no instantaneous drop of voltage but the voltage falls on an exponential curve, and rises

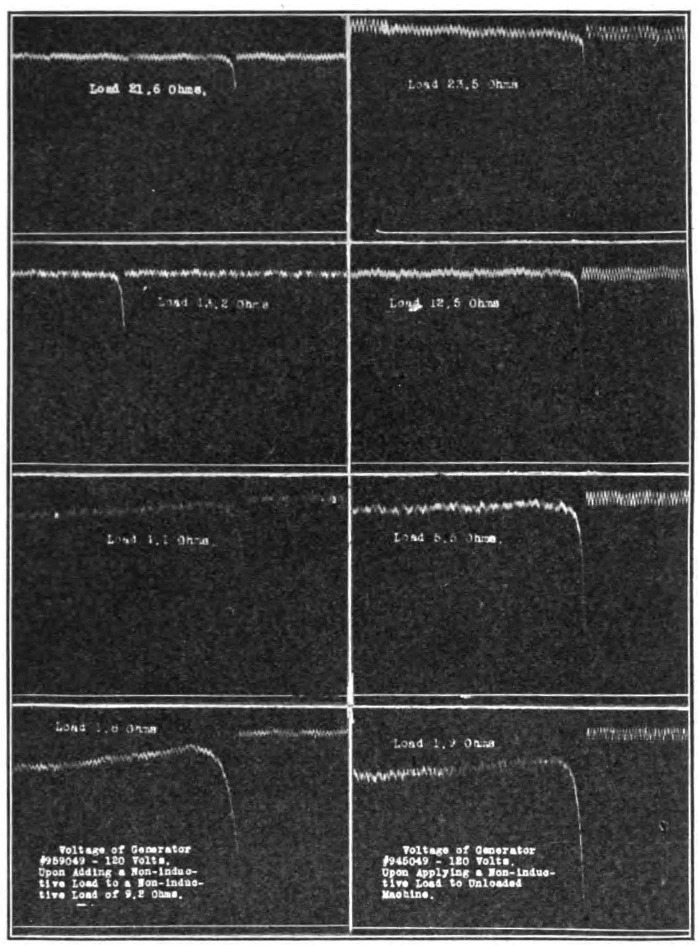


FIG. 8

on a similar curve of smaller exponent value. The voltage across the two branches is alike at every instant and is

$$e = i_1 r_1 = i_2 r_2 + \frac{d i_2 L_2}{dt} \tag{20}$$

where i_1 is the instantaneous value of current in branch 1, i_2 the instantaneous value of current in branch 2. L_2 = the inductance of branch 2.

$$i_1 = I_1 + K\epsilon^{-\alpha_4 t} - K\epsilon^{-\alpha_5 t} \tag{21}$$

where

$$K = (r_2 - \alpha_4 L_2) B$$

where

$$B = \frac{\alpha_5 I_2 - E}{r_1 (\alpha_5 - \alpha_4)}$$

where

$$\alpha_4 = \frac{S - q_1}{2\, L_2\, L_a}$$

and

$$\alpha_5 = \frac{S + q}{2\, L_a\, L_2}$$

where

$$q_1 = \sqrt{S - 4\, r_1\, r_2\, L_a}\, L_2$$

where

$$S = L_a\,(r_1 + r_2) + L_2\, r_1$$

At $t = o$ (**21**) of course reduces to

$i_{1_{t=o}} = I_1$ and the voltage becomes **(22)**

$$e_{t=o} = I_1\, r_1 = E \qquad \textbf{(23)}$$

Fig. 9 is a plot of calculated values for several conditions of steady and added load.

Oscillograms from tests under several conditions of load are shown in Fig. 10 in comparison with similar values of non-inductive load added to a generator carrying non-inductive load. (Case three).

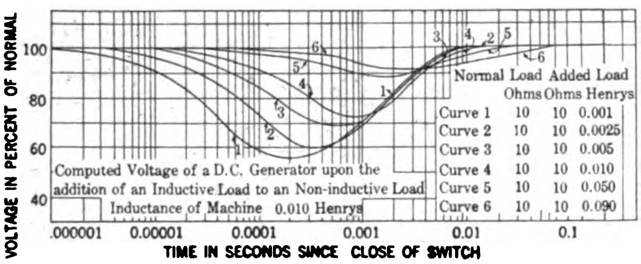


Fig. 9

Case Five

The machine carrying an inductive load, and a non-inductive load added.

In this case there is an instantaneous drop to zero and a building up from there on an exponential curve.

$$e = i_1\, r_1 + L_1 \frac{d i_1}{dt} = i_2 r_2 \qquad \textbf{(24)}$$

where

$$i_2 = I_2 + K_2\, \epsilon^{-\alpha_6 t} + K_3 \epsilon^{-\alpha_7 t} \qquad \textbf{(25)}$$

where

$$\alpha_6 = \frac{S_2 - q_2}{2\, L_a\, L_1}$$

$$\alpha_7 = \frac{S_2 + q^2}{2\, L_a\, L_1}$$

$$S_2 = L_a\,(r_1 + r_2) + L_1\, r_2$$

and

$$q_2 = \sqrt{S^2 - 4\, r_1\, r_2\, L_a\, L_1}$$

$$K_2 = B_2\,(r_1 - \alpha_6\, L_1)$$

$$K_3 = (I_2 + K_2)$$

where

$$B_2 = \frac{I_2}{L_1\,(\alpha_6 - \alpha_7)}$$

Substituting **25** in **24** we get

$$e = r_2\,(I_2 + K_2\, \epsilon^{-\alpha_6 t} + K_3\, \epsilon^{-\alpha_7 t}) \qquad \textbf{(26)}$$

which on equating $t = o$ becomes

$$e_{t=o} = 0 \qquad \textbf{(27)}$$

since in (**26**) both K_2 and K_3 are negative numbers and $-K_2 - K_3 = I_2$.

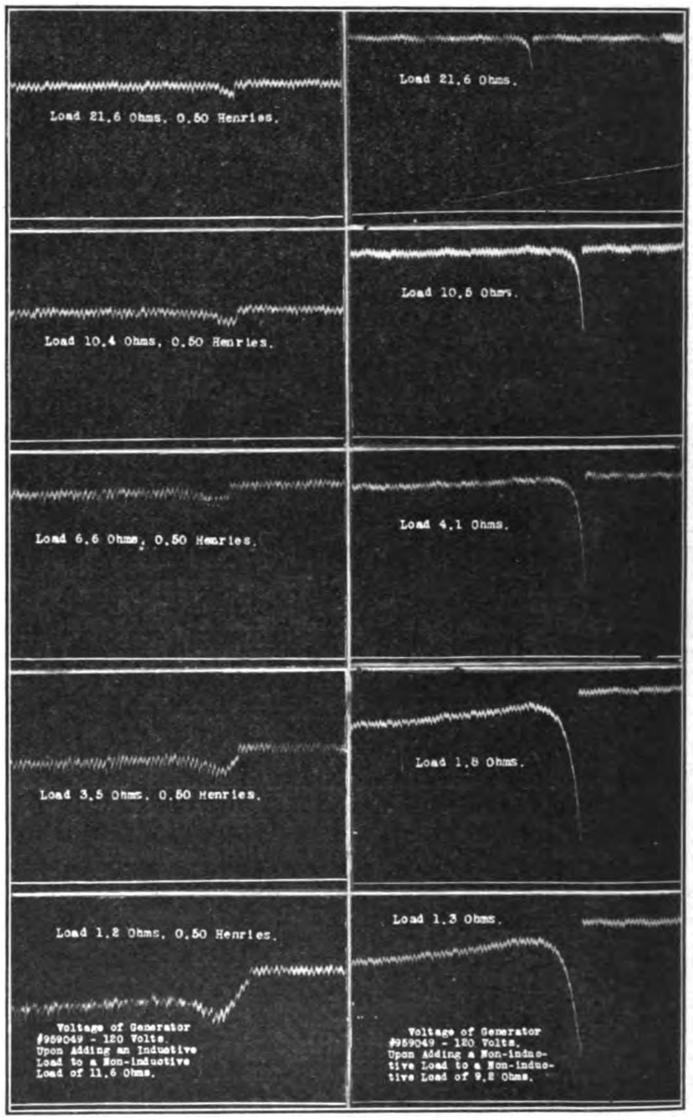


Fig. 10

Fig. 10-A is a calculated plot of several values of load added to a 10-ohm load of variable inductance.

Oscillograms from tests under several conditions of load are shown in Fig. 11 in comparison with similar values of non-inductive load. (Case three.)

Case Six

An inductive load added to an inductive load.

There is in this case an instantaneous drop in voltage, but never to zero. The instantaneous drop is approximately equal to the voltage of the machine, times

the ratio of the added inductance to the sum of the added load and machine inductances. The voltage builds up from this value along an exponential curve of four terms. The current builds up from zero according to an exponential curve of two terms.

$$e_1 = e_2 = i_1 r_1 + L_1 \frac{di_1}{dt} = i_2 r_2 + L_2 \frac{di_2}{dt} \tag{28}$$

$$i_1 = I_1 + K_4 \epsilon^{\alpha_9 t} - K_4 \epsilon^{-\alpha_8 t} \tag{29}$$

where

$$K_4 = B_3 (r_2 - \alpha_9 L_2)$$

$$B_3 = \frac{- I_2 (r_2 - \alpha_8 L_2)}{(r_1 L_2 - r_2 L_1)(\alpha_9 - \alpha_8)}$$

$$\alpha_8 = \frac{S_3 - q_3}{2 L_z}$$

$$q_3 = \sqrt{S_3{}^3 - 4 L_z r_1 r_2}$$

$$S_3 = L_a (r_1 + r_2) + L_1 r_2 + L_2 r_1$$

$$L_z = L_1 L_2 + L_a L_1 + L_a L_2$$

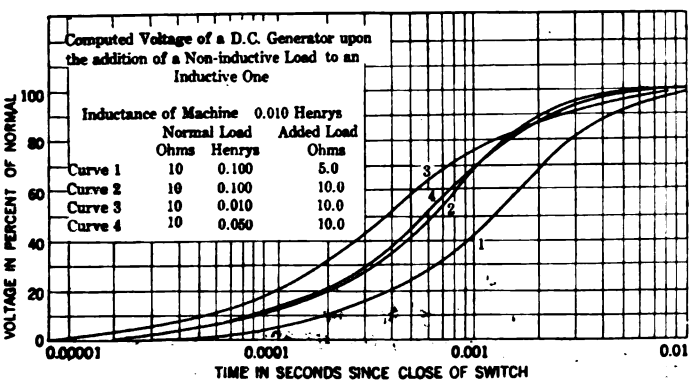


FIG. 10-A

Differentiating (29) we get

$$\frac{di_1}{dt} = - \alpha_8 K_4 \epsilon^{-\alpha_8 t} + \alpha_9 K_4 \epsilon^{-\alpha_9 t} \tag{30}$$

Substituting (29) and (30) in (28) reduces it to

$$e_1 = r_1 \{ I_1 - K_4 [\epsilon^{-\alpha_9 t} - \epsilon^{-\alpha_8 t}] \}$$

$$+ L_1 K_4 (\alpha_8 \epsilon^{-\alpha_8 t} - \alpha_9 \epsilon^{-\alpha_9 t}) \tag{31}$$

This at $t = 0$ becomes

$$e_{1\,t=0} = r_1 I_1 + L_1 K_4 (\alpha_8 - \alpha_9) \tag{32}$$

$$= E + L_1 K_4 (\alpha_8 - \alpha_9) \tag{33}$$

The second term of this expression is always a negative quantity since α_9 is always greater than α_8.

Fig. 12 is a plot of calculated values for several conditions of steady and added load.

Oscillograms from tests under several conditions of load are shown in Fig. 13 in comparison with similar values of inductive load added to a generator carrying non-inductive load. (Case four).

Load Decrements

A load removed from the circuit produces effects opposite to those when load is added, namely, a voltage rise instead of dip.

It is well-nigh impossible to express mathematically such cases or analyze them experimentally, due to our inability to assign proper value to the increasing resistance of the arc that forms when the load is removed.

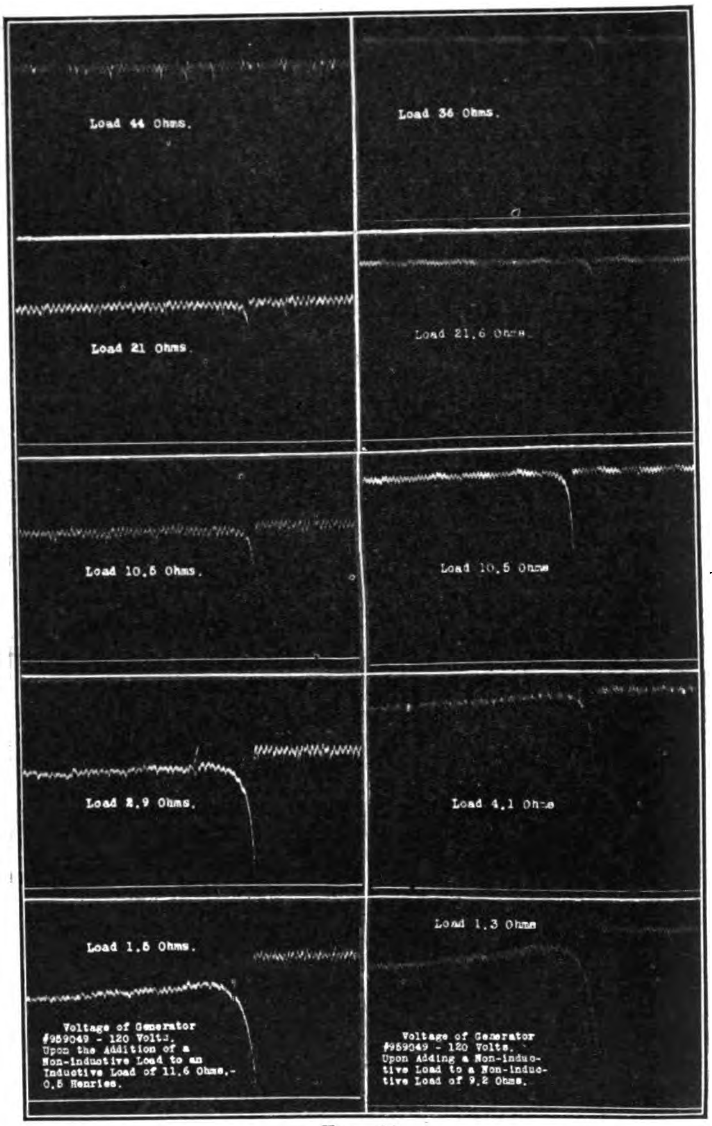


FIG. 11

Conclusion

The foregoing equations can of course be at best but first approximations especially at values well along the recovery curve. No allowance has been attempted for the variation of permeability with flux density, or for the individual characteristics and reactions of machines themselves. However, the equations will be found valuable and reliable for the computation of voltages near the start of the transient, which should make them of value in the determinations of those conditions that would cause flicker of lamps upon the loading of a generator or circuit.

The principles and equations already laid down lead

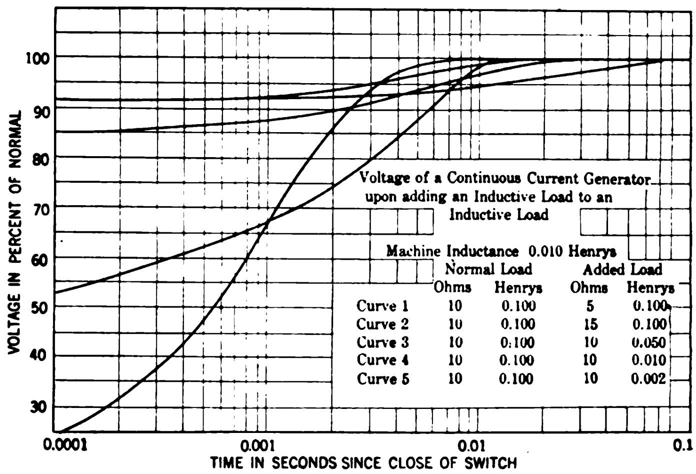


Fig. 12

to some rather unusual conclusions regarding the means of improving the instantaneous regulation of circuits where flickering of lamps is objectionable. The voltage changes that have been discussed are inherent in such circuits, and in general, in large measure are independent of the cross section of feeder or service lines. No matter how large the cross section there will be a voltage dip that is inherent in the circuit, and if the inductance of the series circuit is large enough the application of a load will cause flicker. Being dependent upon the inductance of the circuit for their duration, attempts at their elimination by the compounding of machines are obviously steps in the wrong direction. Better instantaneous regulation will be obtained from shunt machines, than from compounded ones due to the lesser inductance of the former. Not only does compounding lead to a greater duration of transient conditions but the extra windings have no effect on the generated voltage of the machine until the current has risen well along the recovery curve.

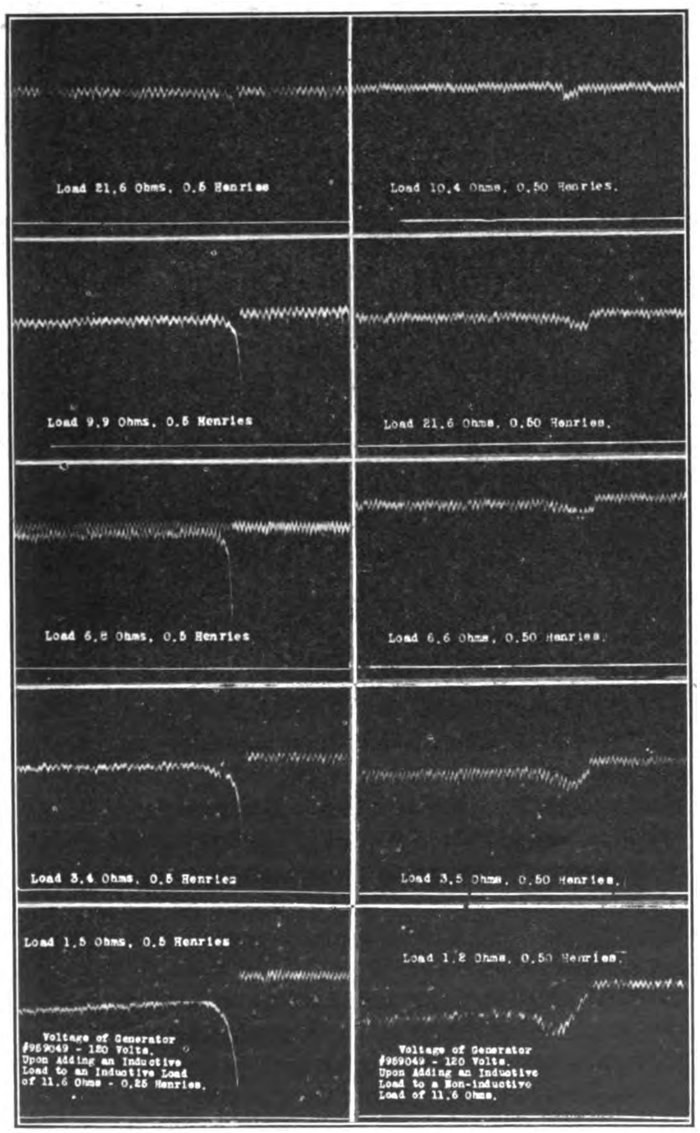


Fig. 13

The disturbances of large loads applied to lines can be mitigated by the insertion of suitable values of inductance coils of low resistance in series with the applied loads. In general the larger the value of the inductance applied the smaller will be the effect of a given load on the rest of the line. The fundamental principles involved in this application were discussed under the second case of load increments. It was there shown that the greater the ratio of the applied inductance to the machine inductance, the less will be the instantaneous drop. The other cases, that of inductance added to loads already on the lines, follow this same principle though the analytical treatment of them is not so simple.

RESEARCH GRADUATE ASSISTANTSHIP

The University of Illinois maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station and two other assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $500 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools.

An appointment to the position of Research Graduate Assistant is made for two consecutive collegiate years, at the expiration of which the degree of Master of Science will be conferred. Not more than half of the time of a Research Graduate Assistant is required in connection with the work of the department.

Nominations to these positions are made from applications received by the Director of the Station each year not later than the first day of March. Preference is given those applicants who have had some practical engineering experience following the completion of their undergraduate work.

The work of the Engineering Experiment Station is closely related to that of the College of Engineering, and the Heads of Departments in the College constitute the Executive Staff of the Station.

Additional information may be obtained by addressing the director, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

Oscillograms and their Tests

BY A. E. KENNELLY, Professor of Electrical Engineering, Harvard University, and the Mass. Inst. of Technology

R. N. HUNTER, Engineering Department, American Telephone and Telegraph Co.

and A. A. PRIOR, Instructor Case School of Applied Science

OSCILLOGRAPHS, as used in electrical laboratories, are divisible into two classes; namely, first, those that employ mechanical vibratory systems, and second, those that employ no mechanical vibratory systems. In the first class, are the great majority of electrical engineering oscillographs. In the second class are Braun cathode-ray tubes. The paper here presented deals only with the first class, or mechanical vibrators.

All mechanical-vibrator oscillographs behave differently to different frequencies, owing to their inherent elasticity and inertia. In other words, their specific deflections[1] and calibrations differ at different frequencies. These differences affect both magnitude and phase. An oscillograph calibrated at, say, 60～ must have a different calibration at other frequencies. In some instruments, the difference may be small, and for many purposes it is often negligible. In other instruments, or for other purposes, the difference may be very serious. But whether the error due to a change in frequency is small or large, it should be measurable, and the amount of it should be either known or determinable to the desired degree of precision.

When the oscillogram of a complex alternating wave form is analyzed, in one of the usual ways, for its Fourier components; *i. e.*, into a fundamental wave and its harmonics, these different harmonics call for their proper corrections, both as to amplitude and to relative phase position. It is not possible for the same calibration to apply to them all. If the instrument has been calibrated at, or near, the fundamental frequency, the apparent harmonic components require correction. The correction factors may be greater or less than unity. They may not be serious, but they should be capable of determination.

These errors of harmonic analysis in oscillograms have been known for some years, as the bibliography of the paper indicates; but no technique for determining the correction factors of an oscillograph at various impressed frequencies has yet been published, so far as the authors are aware.

The paper discusses (1) the theory of an oscillograph with relation to the purpose in view, (2) a device called an oscillograph-meter, which is an auxiliary compact vibrator for determining the resonant frequency of the tested oscillograph, and (3) a number of measurements obtained in this way upon oscillographs in the laboratory.

Theory. The paper points out that there is a complete and valuable analogy between an oscillographic vibrator, or the working part of an oscillograph, and a simple alternating-current branch circuit ($C\ L\ R$ circuit), containing a fixed capacitance C, a fixed inductance L, and a fixed resistance R, all in series across a pair of constant-potential mains, operated at variable impressed frequency. The capacitance C corresponds to the looseness or inelasticity of the mechanical suspension, the inductance L to the mechanical moment of inertia, and the resistance R, to the mechanical torque of frictional resistance to motion in the vibrator. Again, the alternating e.m.f. of the mains corresponds to the alternating torque imposed by a given r. m. s. current passed through the vibrator, and the alternating current strength in the $C\ L\ R$ branch to the angular velocity of the vibrating mirror. This analogy is helpful, because electrical engineers are more likely to be familiar with the electromagnetics of alternating-current circuits than with the dynamics of vibratory mechanical systems.

What the oscillographer desires to ascertain is the maximum angular displacement of the vibrating mirror under constant impressed vibratory torque, but with variable frequency. This displacement bears the same relation to vibratory angular velocity that alternating quantity, or electric displacement in the $C\ L\ R$ branch, bears to alternating current.

It is shown that just as there is the well known impedance Z to alternating current in a $C\ L\ R$ circuit, such that, by Ohm's law, $I = E/Z$; so there is also an impedance Z' to alternating electric quantity, or electric displacement, such that the maximum cyclic displacement is E/Z'. Attention is therefore directed to this "displacement impedance" in a simple branch circuit, which corresponds, in the mechanic analogy, to displacement impedance in the oscillograph.

Bluntness of Resonance. Any mechanical oscillograph, like any $C\ L\ R$ branch circuit, has a certain "bluntness of resonance" B. This quantity may be defined in various ways; but the definition selected in the paper is the ratio of the damping factor to the resonant angular velocity. A vibrator, or a branch circuit, has a bluntness of unity, when its resistance is just sufficient to make it critically aperiodic. If the bluntness is, say, 0.5, then the resistance is half that necessary for critical aperiodicity. Such a vibrator, or circuit, would have a "sharpness of resonance" of $1/0.5 = 2.0$. A bluntness of $B = 3$ would mean three times as much resistance as would be necessary for critical aperiodicity. An air-damped oscillograph ordinarily has a very small bluntness, or a large sharpness of resonance ($B = 0.01$ perhaps). A vibrator damped in castor oil may, on

1. The specific deflection of an oscillograph may be defined as the ratio of its deflection to the r. m. s. current producing the same.

Abstract of a paper to be delivered at the Midwinter Convention of the A. I. E. E., New York, February 20, 1920.

the other hand, have a bluntness greater than unity ($B = 1.2$ perhaps). The most suitable bluntness for an oscillograph, in order to operate with uniformity over a wide range of frequency, is probably near $B = 0.6$. The best value depends on the range of frequency to be covered.

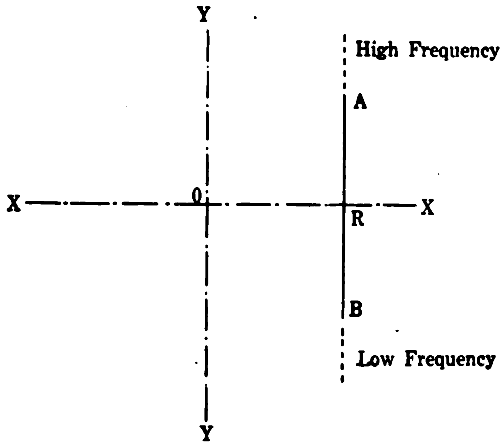


FIG. 1—VECTOR LOCUS OF IMPEDANCE TO ALTERNATING CURRENT IN A $C\ L\ R$ BRANCH, OR TO ANGULAR VELOCITY IN A VIBRATOR

If the resonant frequency f_0 of an oscillograph, and its bluntness B_0, are known, then its correction factor as regards amplitude and phase can be readily computed or tabulated for any or all impressed frequencies.

Displacement Impedance. Whereas the impedance Z of a branch circuit to electric current, at varying

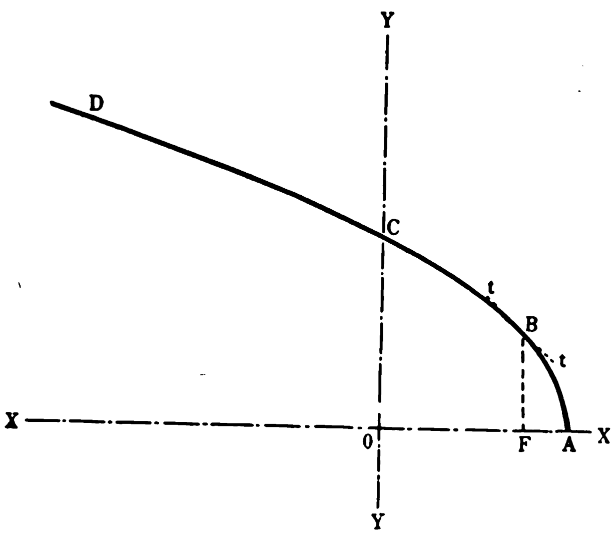


FIG. 2—VECTOR PARABOLIC LOCUS OF DISPLACEMENT IMPEDANCE IN A $C\ L\ R$ BRANCH CIRCUIT OR IN A VIBRATOR

impressed frequency, is a straight line, $A\ R\ B$ Fig. 1, parallel to the Y axis, and passing through the point R on the resistance or X axis at the resonant frequency, the impedance Z' of the branch, to displacement, is a simple parabola $A\ B\ C\ D$ Fig. 2, having its axis on the real axis $X\ O\ X$. At zero frequency, the displacement impedance is $O\ A = 1/C$, and is equal to the reciprocal of the capacitance. As the impressed frequency increases, the vector displacement impedance is OB, OC, OD, and so on. At resonance, it is OC, along the Y axis. The focus F of the parabola lies below the point B, at which the tangent $t\,t'$ is equally inclined to the X and Y axes. Branches or vibrators of sharp resonance have a sharp vector displacement-impedance parabola, and the focus F lies to the right of the origin O. Branches or vibrators of blunt resonance, have a blunt displacement-impedance parabola, and the focus F lies to the left of the origin O. The ratio of the ordinate $F\ B$ through the focus, to the ordinate $O\ C$ through the origin, is equal to the bluntness B_0 of the branch or vibrator.

Displacement Admittance. If we plot the reciprocal of the parabolic vector displacement impedance, we obtain a "displacement admittance" curve, or reciprocal of a parabola, which indicates the magnitude and phase of the displacement produced by unit impressed

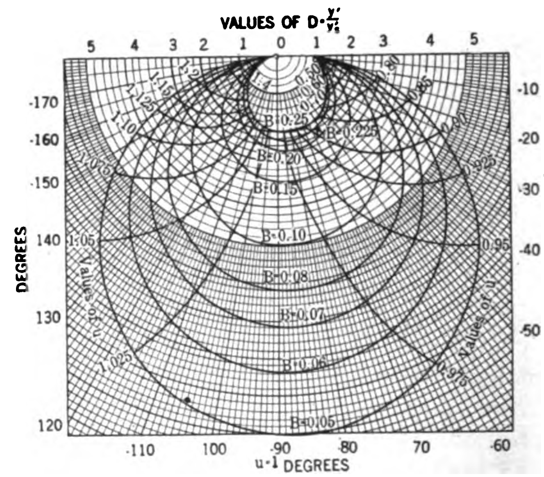


FIG. 3—PLANEVECTOR CHART OF THE DEVIATION FACTOR D FOR ANY OSCILLOGRAPH WHOSE BLUNTNESS LIES BETWEEN $B = 0.25$ AND $B = 1.0$, AND WHOSE RESONANT FREQUENCY IS GIVEN.

EXAMPLE: IF $B = 0.6$, AND $u = 0.3$,
THEN $D = 1.022 / 21.6$ DEG.

e. m. f. in the branch circuit as the impressed frequency is varied. A group of these curves are presented in Fig. 3, between the limits $B = 0.25$ and $B = 1.0$, for various ratios u of impressed to resonant frequency. From these curves, the behavior of any ordinary oscillograph can be read off, by inspection, when the bluntness B, and the resonant frequency f_0 of its vibrator are known. Thus, an oscillograph of bluntness $B = 0.3$, and calibrated at, or near, 60~, would over-indicate in the ratio 1.24 $\nwarrow$ 22 deg. at $0.5\,f_0$, or at an impressed frequency half of its resonant frequency. Its maximum cyclic deflections would be 24 per cent too great at this frequency, and they would lag 22 deg. in phase behind the impressed torque. At $0.8\,f_0$, it would over-indicate in the ratio 1.65 $\nwarrow$ 53 deg., and so on, following the curve for $B = 0.3$.

Technique for Measuring f_0. In order to measure the resonant frequency, which, as indicated in Fig. 3,

is not the frequency of maximum displacement, an optical method is used; *i. e.*, the method of Lissajous figures. An auxiliary permanent-magnet air-damped vibrator, shown in Fig. 4, is supported close in front of the tested oscillograph vibrator, as in Fig. 5. Both vibrators are connected to the same high-frequency source—a Vreeland oscillator or triode vacuum-tube oscillator. The frequency impressed from this source

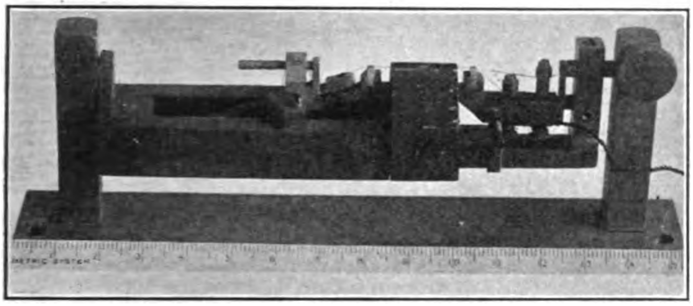


FIG. 4—OSCILLOGRAPHMETER OR AUXILIARY VIBRATOR, LENGTH OF MIRROR 2.3 MM. BREADTH 0.9 MM.

on the vibrators is raised, until the resonant frequency of the tested oscillograph is reached. Then, provided that the auxiliary vibrator is not also nearly resonant, the phase displacements of the two mirrors will be in quadrature. At resonance, the phase of a vibrator always lags 90 deg. behind the impressed torque. The auxiliary vibrator mirror, being air damped, and of very sharp resonance, will be very nearly in phase with

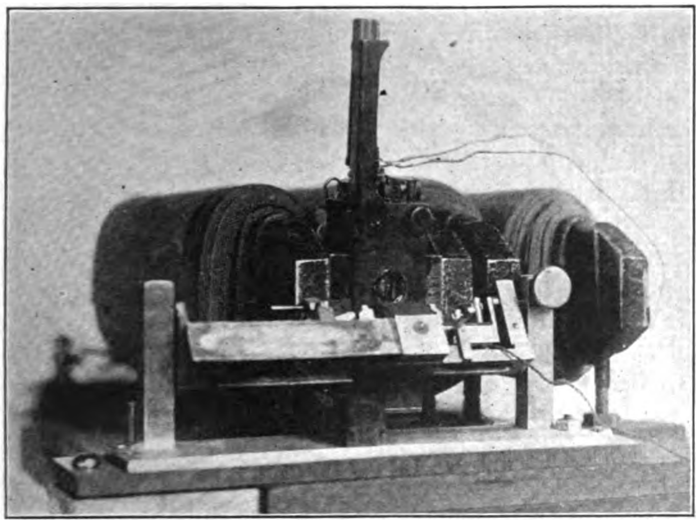


FIG. 5—OSCILLOGRAPHMETER APPLIED TO OSCILLOGRAPH FOR TEST OF LATTER

the impressed torque until the impressed frequency is close to its resonant point. The condition of quadrature between the two vibrating mirrors is easily detected, by throwing a small arc-light beam, first on to the tested vibrator mirror, and then to the auxiliary vibrator mirror, and finally on a fixed screen, the two mirrors having their axes mutually perpendicular. The optical figure perceived on the ground glass or paper screen reveals the quadrature relation.

Technique for Measuring B. Having ascertained the resonant frequency f_0 for the tested oscillograph, as above described, the auxiliary vibrator is withdrawn, and the tested oscillograph is then calibrated at any very low frequency, such as 60~, and again at its resonant frequency f_0. The ratio of the specific deflection at 60 ~, to twice the specific deflection at f_0 is then the bluntness B of the vibrator. This relation can be observed from an inspection of Fig. 3.

Having thus ascertained the fundamental constants f_0 and B of the oscillograph, its behavior at any impressed frequency may be ascertained, either by graphic approximation from Fig. 3, or by means of a formula given in the paper. These fundamental constants f_0 and B should be measured, whenever an oscillogram of a periodic wave form is secured for accurate work, and they may advantageously be recorded, for reference, on the oscillogram itself. Both constants are subject to variation with the temperature of the damping liquid; but, at constant temperature, they appear to be fairly permanent.

Results of Observations. The observations above described have been checked upon a number of vibrators, with satisfactory results. Oscillographic vibrators have resonant frequencies ordinarily lying between 1200~ and 5000~. Their bluntness B depends very largely upon the viscosity of the damping liquid. A vibrator, for example, which in air, had $f_0 = 2635\sim$ and $B_0 = 0.055$, developed in glycoline $f_0 = 1675\sim$ and $B_0 = 0.125$. In mineral oil, these values became $f_0 = 1614\sim$ and $B_0 = 0.288$; while in castor oil, they became $f_0 = 1196 \sim$ and $B_0 = 0.83$.

Tables and curves are presented in the main paper, giving the results obtained on various instruments in the laboratory.

SLAG AS AN AGGREGATE FOR CONCRETE

The results of the investigation made by the Bureau of Standards during the past two years on this subject are summarized as follows: Crushed slag as a coarse aggregate produced concrete of as high or higher strength than gravel. The tests have not been extensive enough to determine the durability of slag, but so far as they have gone, no signs of disintegration have been observed due to sulphide sulphur. Slag sand, because of its lack of fine material, does not produce easily workable concrete when used as fine aggregate. If it must be used, its working qualities can probably be improved by the addition of small amounts of fine sea sand, hydrated lime, or other similar material. In all probability, a larger amount of fine aggregate to replace some of the coarse aggregate would aid workability. Provisions in specifications for slag aggregates calling for a maximum sulphide sulphur content of 1½ per cent and a minimum weight per cubic foot of 70 pounds have been tentatively recommended.

Daylight Saving

BY PRESTON S. MILLAR

General Manager, Electrical Testing Laboratories, New York

"Daylight Saving" is found to reduce the total output of certain central stations and of one gas company by about 3 per cent during the seven summer months. Reduction in output for lighting alone is found to average 8 per cent. Applying these fragmentary data to the country as a whole there is estimated an annual saving by the public of $19,250,000 in expenditure for artificial light and a reduction of about 495,000 tons per annum in consumption of coal.

The principal advantages of "Daylight Saving" are promotion of outdoor recreation, saving in expenditure for artificial light and saving of fuel. Disadvantages are experienced principally by farmers, dairymen, truck gardeners and miners. Economic losses probably far outweigh the gains.

Custom in allocating hours for work, sleep and play has been evolved through experience. It is undesirable to alter it by arbitrary legislation. Since advancement of clocks, while serving the interests of one part of the population, has proved so disadvantageous to another part as to compel return to correct time, it seems obvious that those who benefit by advanced time in summer should adjust their habits as desired without disturbing the practise of the remainder of the population.

IN accepting the invitation of the Lighting and Illumination Committee to present a paper on "Daylight Saving," the author stipulated that in order to consider the subject comprehensively, a considerable part of the paper would have to be devoted to matters remote from electrical engineering. The economic and sociological aspects of daylight saving surpass in importance the effect upon use of artificial light. Any treatment which should ignore these important features would lack perspective and would be likely still further to increase confusion on a subject which is greatly in need of clarification. Accordingly this paper includes a brief survey of daylight saving in its several aspects.

Postponing for the latter part of the paper discussion of the advantages and disadvantages of daylight saving, consideration is first given to the effect upon output of electric plants and upon use of artificial light.

PART I

Reduced Use of Electricity

Effort has been made to secure from central stations and from private plants information which will indicate the effect of daylight saving upon output.

No organized data concerning private plants have been located.[1] The general view of those best informed seems to be that the saving is not of great moment.[2]

Statistics have kindly been supplied by several large central station companies. This opportunity is taken to express the author's appreciation of the cooperation accorded in this connection. These companies operate in the northeastern part of the United States in the region bounded on the south by the Potomac and Ohio Rivers (roughly 38 deg. N.) and on the west by the Mississippi River. Differences in latitude within this region are considerable and doubtless have an appreciable effect upon the use of artificial light. Differences in longitude may of course result in something like one hour greater or less use of artificial light, depending upon location east or west of the meridian with reference to which local time is fixed. However, the variable conditions under which these stations operate and the fluctuations in weather conditions are such as to make impracticable a detailed analysis with reference to latitude and longitude.

The central station statistics have been compiled partly from comparison of output in the years prior to 1918 with the two more recent years, allowance being made for growth of business, and partly from study of daily load curves and daily kilowatt-hours just before and just after change of clocks at the beginning and at the end of the daylight saving periods of 1918 and 1919. Such daily load curves have been reduced to percentages of total daily send-out and have been combined to obtain the composite curves shown respectively in Figs. 1, 2, 3 and 4. The autumn curves differ from the spring curves characteristically due in part to earlier darkness. Beyond this the several composite load curves bear no inter-relation being formed from the data made available for each period of time change, and including in each case different groups of central stations. It is not significant for our purpose, for example, that the ratio of day to evening peak in Fig. 3 is greater than that in Fig. 1. It is significant, however, that in spite of the independence of the four curves they exhibit certain features in common. There is a slight increase in consumption in the early morning under advanced time; a conspicuous valley in the evening; a later and diminished evening peak; and in most cases a slightly increased output in the late evening. The daily load factor is not affected in cases where industrial power absorbs the maximum output. For lighting, as shown later, the output is reduced to about the same extent as the lighting maximum and therefore the daily load factor for such loads is not materially influenced.

In Table I there is a summary of the central station statistics which enter into the construction of the composite load curves in Figs. 1 to 4 inclusive. These

To be presented at the 8th Midwinter Convention of the A. I. E. E., New York, February 18, 1920.

1. For references see end of paper.

show for the time of advancing or retarding clocks in both 1918 and 1919, the number of central stations contributing statistics and the average changes in daily send-out for the entire plants. Certain other information not attributable to particular dates is included as "miscellaneous."

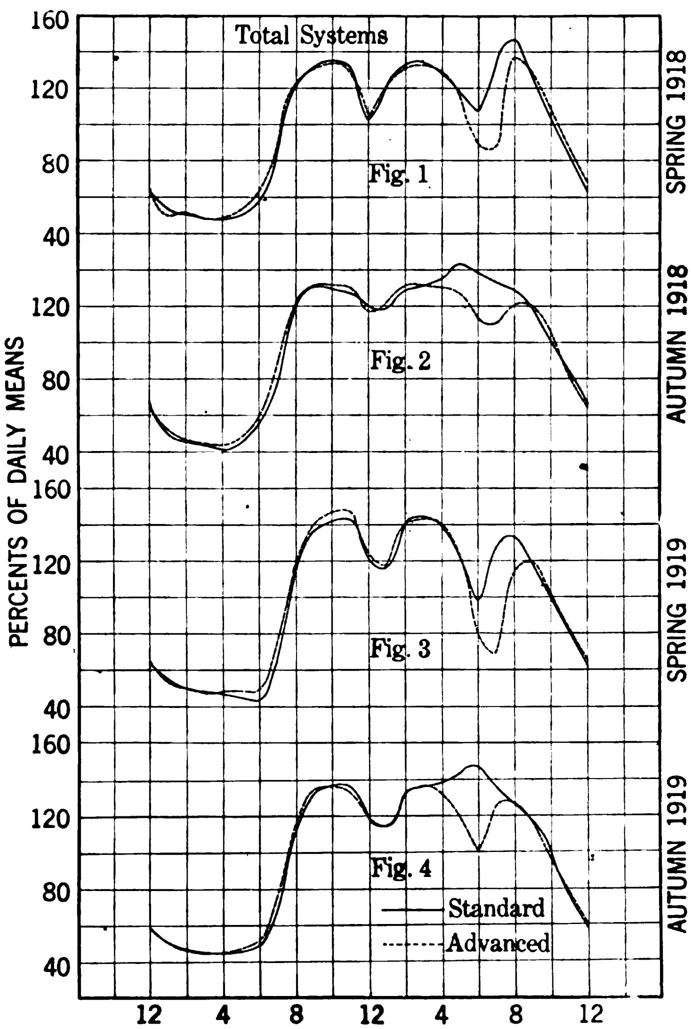
TABLE I
Change in Weekday Output of Central Stations under Daylight Saving

Period	Number of companies	Differences	
		Range	Average
Spring, 1918	16	+ 0.3 to − 9.0	− 3.0
Autumn, 1918	4	+ 4.4 to − 5.7	− 2.0
Spring, 1919	6	+ 3.4 to − 8.0	− 2.5
Autumn, 1919	7	+ 0.7 to − 6.3	− 3.1
Miscellaneous	4	− 0.8 to − 5.5	− 2.4

Variations due to other causes are greater than the average reduction due to daylight saving, some data actually showing increases of output for certain days under daylight saving. The differences are derived principally from comparison of equivalent weekdays ranging in number from one to five before and after change of clocks. No allowance has been made for the natural decrease in use in the first week of advanced time in April as compared with the last week of standard time in March, nor for the corresponding actual increase in use under normal time in the first week of November as compared with that of the last week of October. The effect of ignoring this variable in both cases is slightly to exaggerate the indicated reduction in use of electricity due to daylight saving.

The average data for the several periods yield reasonably concordant indications as to the extent of the effect upon daily send-out at the beginning and end of advanced summer time. The average reduction in daily kilowatt-hours is shown to be of the order of 3 per cent. There is reason to believe that in the interval between these periods the reduction is not markedly different. Accepting 3 per cent therefore as representative of the extent to which in our general latitude during the seven summer months the kilowatt-hour output of central station plants is decreased, it is possible to form a rough estimate of the amount of coal saved by central stations and of the amount of money saved by the public through the less use of electric light.

In ordinary circumstances good judgment would probably dictate that one refrain from hazarding estimates of these kinds due to the inadequacy of information and to the wide range of conditions throughout the country, many of which depart materially from the conditions of operation of the companies included in this survey. Much unreliable information has been published, however, purporting to indicate the extent of saving in fuel and money growing out of advanced summer time, and it would appear desirable therefore to offer a reasonable estimate based upon the data here made available. In undertaking to do so it is to be emphasized that the data in this paper are quite meager. Of the many central stations in the country only a very few are represented. In consequence these estimates are to be regarded as only rough approximations which are probably well indicated by the available information but which may depart considerably from real accuracy when made the basis of assumptions for other localities or for the country as a whole.



Estimate of Reduction in Expenditure for Electric Light.

One estimate of saving to the public in cost of electric light is made by estimating the total output of central stations, under normal time, considering 3 per cent to have been saved, and assuming a rate of six cents per kilowatt-hour as applicable to such savings. Another estimate is made by pro-rating over the entire country estimates of total annual savings in particular cities.

Estimated total annual output of steam central stations for light and power if normal time had prevailed in 1918 or 1919[3]	14,375,000,000	kw-hr.
Ditto for seven summer months	8,000,000,000	"
3 per cent of above	240,000,000	"
At six cents		$14,400,000

	Range	Mean
Published estimates per capita[4]	21 cents to 24 cents	22 cents
Private estimates per capita[5]	14 cents to 21 cents	19 cents
Assigned		21 cents

Estimated total annual savings at 21 cents of 60,000,000 people in communities served by steam and water plants	$12,600,000
Assigned annual value of reduced expenditure for electric light supplied by central stations	$14,000,000

How much of this is to be considered actual saving to the public is an unanswered question. The long

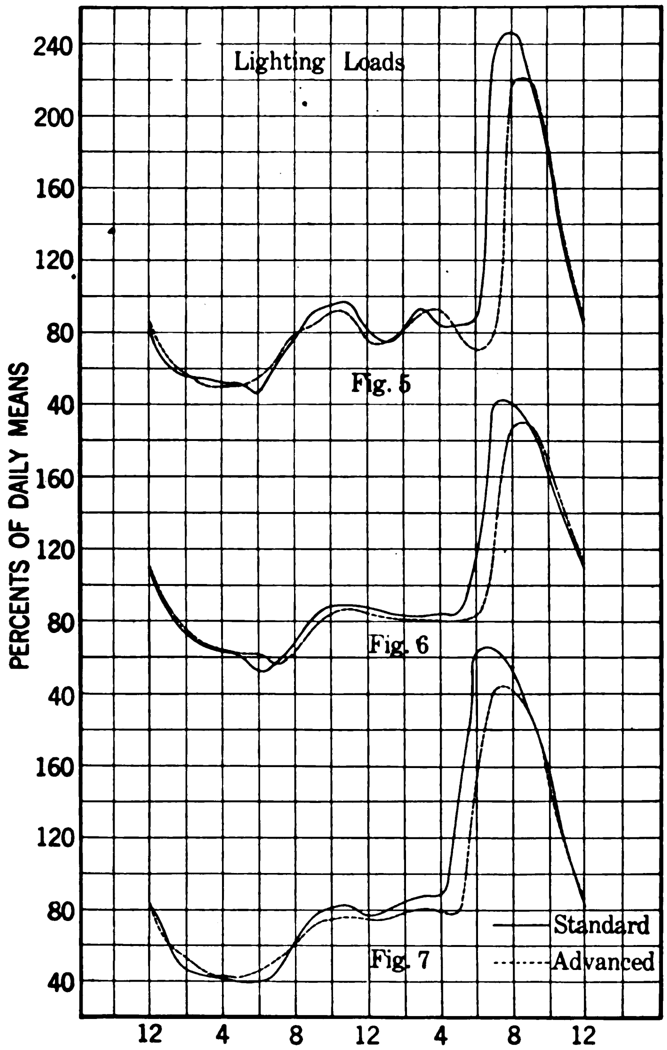


Fig. 5
Fig. 6
Fig. 7

continued downward trend of rates for electricity was halted by increased costs growing out of the World War. The effect upon central stations of daylight saving has been in a small way to reduce revenues from electric lighting without affording opportunity for compensating reductions in cost. This has contributed to a very slight extent to halting the downward course of rates and to bringing about increases in rates here and there, where these have been found necessary. Furthermore minimum rates for service in force in many localities limit the reduction to smaller amounts than those entering into the foregoing estimate. In view of these conditions it is a question what part of the $14,000,000 estimated to be the aggregate reduction in payment by the public for electric light should be considered to be an actual saving to the public.

Saving in Coal. Taking the above estimate of kilowatt-hours as the annual reduction in output of central stations due to daylight saving, and estimating a coal saving rate of say 2½ pounds per kilowatt-hour, we arrive at an estimate of 300,000 short tons of coal saved per annum.

Reduction in Residential Use of Electricity. All of the foregoing has been based upon statistics as to the total daily send-out of central station plants. It is in residential lighting that the effect of daylight saving is most conspicuous. Through the courtesy of certain central station companies it has been possible to obtain information as to the daily kilowatt-hours and daily load curves of certain substations or feeders which are devoted largely to the supply of residential districts, and certain Sunday records which are of a somewhat similar character. These have been consolidated and are presented in Figs. 5, 6, and 7. The valley in the late afternoon occasioned by daylight saving is again seen, the shifting of the peak and the decrease of the maximum are evident and there is exhibited a tendency for people to use light to a later hour according to the clock than under normal time, thus indicating a tendency to sit up later. In passing it may be noted that certain telephone statistics in the spring of 1918 tended to confirm this conclusion.

Statistics accompanying daily load curves for residential service are summarized in Table II.

TABLE II
Change in Output of Central Stations for Lighting under Daylight Saving

Period	Number of companies	Differences: Range	Differences: Average
Spring, 1918	4	− 2.0 to − 19.0	− 9.0
Spring, 1919	5	− 5.3 to − 9.1	− 7.0
Autumn, 1919	3	− 5.0 to − 12.6	− 8.5
Miscellaneous	2	− 7.0 to − 7.0	− 7.0

The principal interest in this connection has to do with reduction in the use of artificial light under daylight saving. The indication here is that by and large this amounts to approximately eight per cent in residences.*

*R. S. Hale, *Electrical World*, January, 1920 estimates for Boston residence customers paying $100 per annum a saving of 8.3 per cent and for residence customers paying $20 per annum a reduction of 6.8 per cent during the 7 summer months.

An interesting further study of the reduced residential use of electricity due to daylight saving is afforded through statistics kindly supplied by one central station company to show average kilowatt-hours per residence during each month of the years 1916 to 1919 inclusive. (1919 up to October; estimated for November and December). These are analyzed by a method growing out of a suggestion by Mr. W. F. Wells. The monthly kilowatt-hour averages for 1916 and 1917, prior to the daylight saving period, have been combined and reduced to percentages of the mean monthly value. A like course has been followed in analyzing the 1918-1919 statistics. To the latter, however, a uniform factor has been applied reducing the monthly values to equality for the average of the five winter months with the average of those of 1916-1917. Thus the two curves coincide approximately for the winter months and departures during the seven summer months may reasonably be considered to have been

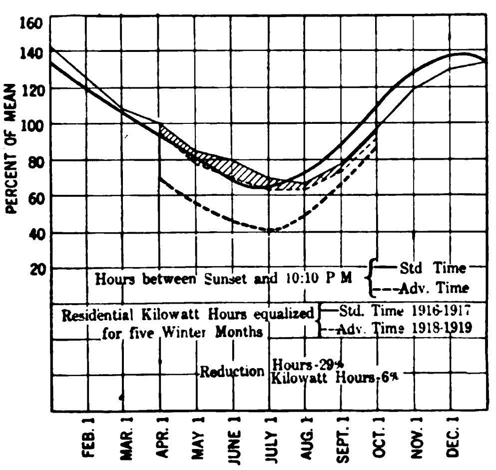


Fig. 8.—Effect of Advancing Clock by One Hour (Latitude 40° N.)

due to daylight saving. For comparison the elapsed time between the hour of sunset (latitude 40 degrees north) and 10:10 p.m. has been taken. This is chosen with a view to making the range of artificial lighting hours employed in this analysis co-extensive with the range in monthly kilowatt-hours. Incidentally, for the beginning and end of the daylight saving period these hours of artificial lighting are found to center fairly well upon the evening peak as indicated in Figs. 5 to 7. In Fig. 8 the hours of artificial lighting thus chosen are indicated by the heavy continuous curve for the several months of the year. The reduction in such hours occasioned by the advancement of the clock in summer time is indicated by the broken heavy line. Both are expressed in per cent of the yearly mean of such hours of artificial lighting. This shows that advancement of the clock during the seven summer months means a reduction by 29 per cent in the evening lighting hours. The light continuous line indicates relative monthly kilowatt-hour consumption of residences in 1916-1917. The relative consumption during the daylight saving period is indicated by the light broken line. The reduced use during this period is represented by the cross-hatched area. This indicates for the city represented in this analysis a reduced use in residences of six per cent.

Reduced Use of Gas

As the preparation of this paper approached completion, it was suggested that a useful purpose would be served by including some information to show the reduction in use of artificial gas due to daylight saving. Hurried requests to a gas company for information met with cordial and prompt response, as a result of which the author was kindly given access to the records of gas send-out. The company operates in the same general region described for electric companies.

In the gas business ordinary variations of output from day to day greatly exceed in magnitude any effect to be anticipated from daylight saving. These fluctuations are so marked and so difficult of explanation as to deter those in responsible positions in the industry from hazarding an estimate of the effect of daylight saving—a view which the records show to be based upon sound engineering judgment. The author, however, after studying the records of this gas company with considerable care, has arrived at an estimate which he feels justified in putting forward as his opinion for which the officials of the company are in no way responsible.

Reduced Use of Artificial Gas. Resorting to graphic analysis it has been possible to extort from apparently inconsistent data of send-out at the time of change of clocks an indication as to the effect of daylight saving. In the case of this one company there is indicated a reduction of about three per cent in the total gas output per day due to daylight saving. It is interesting to note that this entirely independent estimate is closely in accord with the average assigned for reduction in use of electricity. The author assumes that the three per cent indicated as the reduction at the beginning and end of the daylight saving period, as in the case of electricity, is fairly representative of the effect during the intervening months. It is equivalent to about 1½ per cent for the year as a whole.

Coal Saved Through Reduced Use of Gas. It has been estimated that in a year preceding the introduction of daylight saving the net consumption of coal in the manufacture of gas aggregated 10,500,000 short tons.[6] If an increase to 13,000,000 be assumed for a daylight saving year, and if one-half that amount be attributed to the seven summer months, there is a total of 6,500,000 tons, 3 per cent of which gives 195,000 tons as a rough estimate of coal saved. An additional reduction was of course effected in the use of oil.

Reduced Expenditure for Gas. A U. S. Government report for 1915[7] estimated the annual manufacture

of artificial gas to be 284 billions cubic feet. Assuming that for a daylight saving year this was increased to 350 billions, one-half of which was produced during the seven summer months, and using the estimate reached in this paper of three per cent reduction, there is indicated a saving which at $1.00 per thousand cubic feet equals $5,250,000.

Summary of Effect upon Use of Artificial Light

In asking indulgence for the inadequacy of data entering into these estimates the author begs to submit that he is not directly associated with either of the industries affected but must request from them statistics which are necessary for this purpose. In thus imposing upon the good nature of others it was in order to exercise some restraint, requesting information which might be readily available instead of asking for particular details the procuring of which might involve much effort and cost. The material which has been so courteously offered is believed to be reliable and representative. If by reason of its inexhaustive nature or because of poor judgment of the author in its analysis the estimates are in need of revision that fact will doubtless be made known in discussion of the paper.

Summing up this first part of the paper the following table is presented:

Approximate Estimates of Savings During Seven Months Due to Reduced Use of Artificial Light

	Reduction in total output	Saving in coal	Saving in expenditure for artificial light
Electricity (Central Stations)	3 per cent	300,000 tons	$14,000,000
Artificial gas	3 per cent	195,000 tons	5,250,000
Totals		495,000 tons	$19,250,000

PART 2

Historic Note

Benjamin Franklin is considered to be the father of daylight saving.* In 1784 Franklin[7A] stated that by rising with the sun, Parisians might save one hundred million francs annually through the reduced use of candles. He suggested that the public be compelled to practise economy in this matter. A tax of a louis per window shuttered in the morning after sunrise was to be a first step.

Every morning as soon as the sun rises let all the bells in every church be set ringing and if that is not sufficient, let cannon be fired in every street to wake the sluggards effectually and make them open their eyes to see their true interest.

Again Franklin says in his Autobiography—

In walking through the Strand and Fleet Street one morning at seven o'clock I observed there was not one shop open though it has been daylight and the sun up above three hours; the inhabitants of London choosing voluntarily to live much by candle light and sleep by sun light and yet often complain a little absurdly of the duty on candles and the high price of tallow.

In modern times William Willett was sponsor in England for a proposal to advance the clock in summer time in order to utilize daylight to better advantage. The subject in England was agitated from 1908 to 1914 without avail.[9] On May 1st, 1916, Germany as a war measure adopted the plan by advancing clocks one hour for the summer period; England, France and several other countries took like action within the next few months.

On this continent the experiment of advancing the clock had been tried in several localities with varying success.[8] It was adopted in Cleveland in the spring of 1914 by changing from central to eastern time. As Cleveland lies properly just within the western boundary of the eastern zone, this was not a very radical change. It proved successful and has been continued throughout the entire twelve months of succeeding years. In the spring of 1919, when standard time was advanced by federal law, Cleveland advanced its time another hour. This gave rise to much complaint, however, and clocks were retarded on May 11th, 1919, thereby bringing Cleveland to normal eastern time, this last adjustment being still in effect. In Detroit, which lies just within the eastern boundary of the central zone, the clocks were advanced on May 15th, 1915, bringing the City into conformity with normal eastern time both in summer and winter.

In the United States at large agitation for clock advancement in summer time became more pronounced. The National Daylight Saving Association was formed to promote the plan, and the project was furthered by reports of committees of, among others, the Boston Chamber of Commerce and the Chamber of Commerce of the United States. Finally a bill passed by both Houses of Congress was approved March, 1918, fixing standard time to govern the movement of common carriers engaged in interstate commerce and other activities under federal jurisdiction, and providing for the advancement of such standard time by one hour during the period between the last Sunday in March and the last Sunday in October. The States of New York and Pennsylvania adopted parallel legislation to govern state activities. The Federal Act remained in force for two years but that provision which called for advanced time during the summer months was repealed in August, 1919. The repeal became effective at the end of the daylight saving period in 1919.

*Perhaps the first recorded instance of daylight saving is that brought about by Joshua. The Biblical account relates several miracles by which the bloody conquest of Canaan was accomplished. In the rescue of Gibeon which was besieged by the associated kings of the Amorites, Joshua, even though aided by a hailstorm which slew more of the enemy than did his army, was unable to "mop up" before dark. So he spoke to the Lord and caused the sun and moon to stand still about a whole day and there was no day like that before it or after it.

In European countries such as England, France and Germany, after extended trial, the daylight saving plan will probably be followed during the coming summer as in the recent past. In Canada, after a trial during 1918, proposed renewal of the daylight saving bill was defeated in the Dominion Parliament in 1919. It is understood also that in Australia after a trial daylight saving has been abandoned.

Since the repeal of the Federal Daylight Saving Act in this country the subject has been agitated locally in several cities. For example, in Cincinnati advanced time has been adopted to be effective during the entire year, thus conforming to the action of Cleveland and Detroit. In New York, Hartford, Philadelphia, Pittsburgh, and other cities, provision has been made for advanced time in municipal activities during either five or seven summer months. In Chicago after consideration it has been decided to adhere to normal federal time.

After a year's experience in England a Parliamentary committee conducted an investigation of "Summer Time" (clocks advanced by one hour) and reported in favor of its continuance.[9] In the United States there has been no organized investigation of its operation.

Advantages and Disadvantages of Daylight Saving

The advantages which in advance of adoption the measure was said to offer were principally: increased opportunities for outdoor recreation, reduced consumption of fuel, saving in expenditure for artificial light and promotion of gardening. The disadvantages which were anticipated included confusion in railway schedules, confusion as between astronomical and legal time, and possible interference with children's sleep. The author has reviewed the literature of the subject and has instituted inquiries with a view to collecting information on these and other advantages and disadvantages. In consequence there is at his disposal a great mass of opinion but very little definite information. From these the following statement of advantages and disadvantages has been prepared.

Outdoor Recreation. To those engaged in sedentary pursuits and who are in a position to devote spare time to outdoor recreation, daylight saving undoubtedly has been a boon. Public playgrounds and parks of our cities have borne witness to the stimulation which daylight saving has given to outdoor sport. Tennis and golf (Fig. 9) have become more popular, conferring benefit upon many who probably without the additional hour in the afternoon would not have found it practicable on weekdays to avail themselves of these forms of exercise. Opportunities for pleasure automobiling on weekdays have been multiplied. Amateur baseball, and in general unorganized forms of sports, have been promoted. Business men who maintain their own homes have found an added opportunity on weekdays to carry out in daylight the numerous maintenance operations which fall to their lot. In general, the effect of daylight saving has probably been to promote outdoor living with greater enjoyment of daylight by all members of families. Those who could and did avail themselves of the added opportunity have undoubtedly derived physical benefit which has reacted mentally and increased their value to the sedentary occupations in which they are engaged during business hours. Moreover there was probably a wholesome tendency as time passed for more and more people to avail themselves of such added opportunities.

Fig. 9 Photo by Underwood and Underwood

Coal Saving. In Part 1 of this paper it is estimated that the reduction per annum in consumption of coal for lighting is of the order of 495,000 tons. This includes electricity for lighting supplied by central stations and artificial gas.

Saving in Expenditure for Artificial Light. The saving in expenditure for electricity and artificial gas is estimated in Part 1 to be of the order of $19,250,000.

Gardening. The amateur gardening movement was more or less coincident with the large increase in the cost of living which began in 1915. Novelty, recreation and economic advantage all played their part. To this after we entered the war there was added patriotic aspiration.[10] The added hour between the close of business and dark probably assisted amateur gardeners (Fig. 10).[11] It is difficult to determine with what part of the increase in such garden produce it should be credited.

Private gardening was carried on to an increasing extent in suburbs and small towns and in the country before the advent of daylight saving. There is no indication that the daylight saving measure either added to or detracted from private gardening.

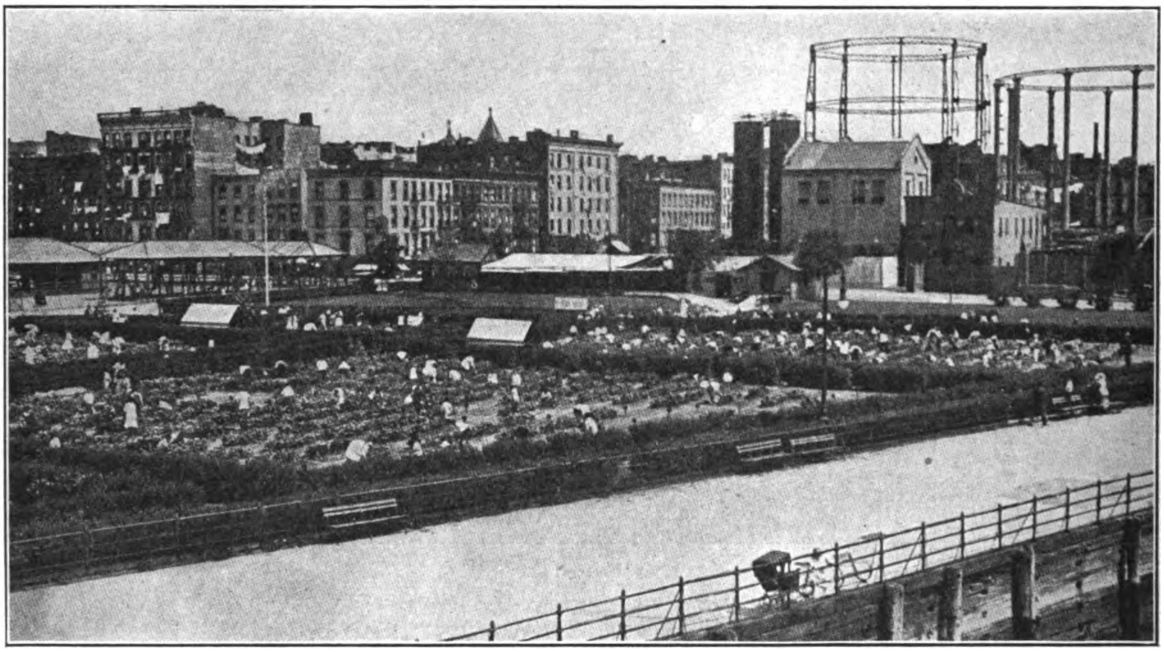


FIG. 10 From "The War Garden Victorious"—Lippincott

Gardening by those who produce a surplus for sale has been impeded by the Daylight Saving Act. Truck gardeners in general have opposed the measure. Vegetable and market-growers' associations in several parts of the country have demanded its repeal. The general reasons given are that advanced time compels gardeners to begin their activity too early for agricultural purposes, but necessarily early in order to maintain contact with the market. These people have to go to bed in daylight or sacrifice sleep.

Upon the whole the evidence appears to be that the disadvantages to professional gardeners of daylight saving have outweighed the advantages to amateur gardeners.

Health. There appears to have been no organized study of the effect of daylight saving upon health.[12] The Federal Public Health Service[13] has no definite information on the subject. The American Medical Association while calling in June, 1919 for a continuance of daylight saving[14], appears to have based its action upon the belief that increased opportunity for outdoor recreation has probably added materially to health and vigor.[15] There is a general view among hygienists that facilities for recreation during daylight are advantageous to those who can and do avail themselves of them.[16] Although there is lack of definite information showing benefit to health, yet it is probable that real improvement has accrued to certain classes of urban and suburban dwellers.

There seems to be practically a consensus that advancement of the clocks in summer brings bedtime for small children well into daylight and interferes with their sleep. Thus children either sit up later or after retiring remain awake later by the clock than formerly. Just how much weight is to be given to this disadvantage is for hygienists to determine.

Those who live in city tenements as a rule have neither time nor money for the forms of outdoor recreation which are promoted by daylight saving. With the day's work finished their desire is more for rest than for recreation. Their homes lack many comforts and are often ill ventilated and congested. In summer it is a problem with these people to get sufficient restful sleep. The arrival of bedtime finds bedrooms uncomfortably hot and stifling. Recourse is bad to sleeping on fire-escapes, and in extremely hot weather to sleeping in parks, and for those who can do so, on beaches.(Fig. 11). To these people daylight saving is disadvantageous during the summer months. They must choose between retiring to their uncomfortable rooms one hour earlier or losing sleep. On the other hand they must arise one hour earlier in the morning at a time when the most refreshing sleep is

to be had. It is said to be the judgment of nurses and visitors who are constantly going in and out of tenement homes that this is an appreciable factor.

A conclusion as to the effect upon health should be reached after weighing on the one hand additional outdoor recreation on the part of those who can avail themselves of the added opportunities, and on the other hand interference with the sleep of children, with the sleep of all who must retire before dark in order to rise early, and with the sleep of all in this climate in hot weather.

Farmers. The most serious complaints concerning disadvantages of daylight saving have come from farmers. To this class is to be attributed most of the influence which led to the repeal of daylight saving. One cannot peruse the agricultural journals and the reports of Congressional hearings on daylight saving without being impressed with the practical unanimity and earnestness of the farmers' opposition.[17] The

Fig. 11 Photo by Brown Brothers

crux of the difficulty is that much of the farmers' work must be regulated by the sun, compelling him to work under normal time, while certain activities as a practical matter have to be adjusted to conform to advanced summer time. The conflict between the two is intolerable. In order to connect with milk trains the schedules of which cannot well be altered because they must serve those who abide by advanced time, it is necessary for the farmer's day to begin one hour earlier than usual. In order that children may attend to chores and get off in time for school, there is the same requirement for earlier rising. This earlier rising in itself is objectionable. The early morning work completed, it is necessary to wait for certain cultivating and harvesting purposes until the dew is evaporated. In considerable part this hiatus means waste. Generally speaking, the farmers who produce surplus food products employ labor. Hired labor is unwilling to work one hour later than do those not engaged in agricultural work. Quitting at the usual clock time, there is a loss of the hired man's time. The farmer himself on occasions when he desires to go to the neighboring town for business, recreational or social purposes must quit one hour earlier, sun time. The curtailment of farming activity thus occasioned is at the time of day which is best for planting and harvesting purposes.

Farmers refer to the measure as "Daylight Wasting."[18] It is obviously difficult to arrive at a definite statement of resultant loss, but some estimates will prove suggestive. It is estimated that the efficiency of farm help is reduced 15 per cent.[19] The loss to farmers involved in daylight saving is estimated to run 18 per cent as the average of a number of farms.[20] Daylight saving is estimated to have added 15 to 20 per cent to the cost of production on farms.[20] United States Senator Capper of Kansas estimates that daylight saving occasions waste aggregating $1,000,000,000 a year.[21] While it is impossible to make any definite statements, yet it is evident that the disadvantages to farmers are large. As a result, agricultural organizations and journals are very generally opposed to daylight saving.[17]

Dairying. In dairy farming the objections to daylight saving are quite as strong as in agricultural work. To accommodate advanced time cows must be brought in for milking in the morning one hour earlier than usual, and sometimes before daylight. Again they must be brought in in the hottest part of the afternoon. Aside from the inconvenience and hardship which this works upon the dairy farmer, it is stated that there is a very noticeable decrease in the milk yield, one estimate placing the quantity as high as two quarts per cow per day.[22] Under conditions with which the author is personally acquainted on a large dairy farm, a somewhat smaller but quite noticeable reduction has been experienced. It is understood that there are about 300,000 cows in New York State alone. It will readily be seen that the loss in milk will aggregate several millions of dollars.

Miners. Next to farmers, miners have probably protested against daylight saving more than any other class of people. This is especially true of those in the Middle West. It is necessary for their wives to rise before daylight to prepare breakfast and pail luncheon, and for the miners to leave home unduly early (sun time) in the morning. At the other end of the day this means retiring while it is still light in the heat of the evening.[23]

American Federation of Labor. Delegates to a convention of the American Federation of Labor expressed themselves as in favor of the daylight saving project when the plan was proposed during the war. Officers of the Federation have continued to favor the plan. At the convention of the Federation in June, 1919, however, the delegates voted in disapproval of daylight saving.

Financial Relations with Europe. One point claimed for advanced summer time was that it would bring

exchanges in this country into better contact with those of Europe, due to overlapping of hours of active trading. The author is advised that no advantage has been realized, however, because arbitrage transactions by cable have been out of the question since the outbreak of the Great War.

Accidents. Another claim advanced for daylight saving was that there would be fewer accidents in industrial districts under advanced time. No information is available to show that such has been the case. Inquiry has brought advice that it would not appear that there has been any appreciable benefit which could be traced to the advent of daylight saving.[24]

Summary of Advantages and Disadvantages. Examined in the light of such information as is available, daylight saving is seen to have promoted outdoor recreation on the part of those who were in a position to avail themselves of the opportunity afforded. It has saved fuel although the amount of saving is less than has been claimed. It has reduced expenditure by the public for artificial light but to an amount less than has been stated.

There is nothing to show that the net effect upon the health of the people as a whole has been either beneficial or harmful. Its effect upon financial relations with Europe has not been felt. No effect upon accident rates has been observed.

Its effect upon gardening and garden produce has probably been more harmful than beneficial. It has interfered with the sleep of small children, and has probably caused discomfort to urban poor. Farmers have been inconvenienced, and the efficiency of farm labor has been decreased. Estimates indicate that agricultural losses of a large order have been occasioned. Dairying has been interfered with, and milk yield of cows has been diminished slightly. Miners have been inconvenienced.

Author's Deductions and Opinions*

During the agitation leading up to adoption of the Daylight Saving Act in the spring of 1918, the writer paid but little attention to the subject. He first became interested as a result of being called upon to make a presentation on the subject before the war meeting of the National Electric Light Association in 1918. Being but little affected one way or the other by advancement of the clock he undertook an examination of the subject fairly free from prejudice, and has followed the development of the discussion and has talked with various classes of people and has observed the workings of advanced summer time with increasing interest ever since.

Why do we Distribute the Hours of the Day as at Present? A natural question growing out of the proposal to advance summer time was early recognized; namely, why have we adopted existing hours for work, play and sleep? There has been no legislation necessitating the adoption of particular hours. There was not even federal legislation fixing standard time until the passage of the Calder Daylight Saving Act in 1918. Yet in our own time and in earlier times it has been the practise to postpone retiring considerably beyond the end of daylight and to remain in bed considerably beyond sunrise in the summer time. Even in the days of tallow candles, as evidenced by the strictures of Franklin excerpted in the Historical Note of this paper, it was customary to postpone retiring, thus incurring considerable expense for artificial light of a most inferior quality.

In searching for an explanation of this fact, the author arrived at the conclusion that our practise in distributing the 24 hours is the result of a compromise between considerations of light and temperature. It would appear that time of retiring and rising and choice of hours for work and for recreation may be varied considerably in the spring and in the autumn without incurring any disadvantage growing out of temperature extremes. In winter and in summer, however, temperature extremes impose limitations upon living conditions which cannot be ignored. In winter time the problem is to keep warm. In earlier habitations and in dwellings of the poor today, this problem is especially difficult. There is no place where it is quite so easy to keep warm as in bed. When the heating problem is difficult therefore, the natural thing to do is to spend in bed the hours of lowest temperature. In summer the problem of securing restful sleep is one of keeping cool. Considering the way in which indoor temperatures lag behind outdoor temperatures in summer, the choice of hours for most comfortable sleep, if guided alone by the temperature consideration, would be even later than in the winter. Customs tend to become fixed, however, and again a compromise between temperature conditions and light conditions appears to have been reached in the choice of hours for sleep.

Fig. 12 gives for three representative months of the year under New York conditions, fluctuations in outdoor light and temperature. If one were to choose the eight-hour period of the 24 in which outdoor temperature upon the whole is lowest, he would probably select the period 1 a.m. to 9 p.m. The actual period for sleep taken in the diagram as 10:30 p.m. to 6:30 a.m. seems to be a compromise between a choice of the lowest temperature period and a choice of the period of darkness for sleep purposes. It appears to the author that the allocation of time to sleep, work and play has been dictated in part by a choice of the most suitable hours for sleep as well as by choice of the most suitable hours for work. Therefore the arbitrary advancement of clocks by

*The author's thanks are extended to those who have given him the benefit of suggestions and criticisms and to whom he is greatly indebted in connection with the preparation of this paper.

one hour in the summer time upsets the deliberate custom of a whole people, which custom has been arrived at through experience in which the only consideration has been the greatest comfort and advantage of the greatest number of people. Left to choice in summer time the majority of people would probably prefer to go to bed later and rise later in the morning rather than to go to bed and rise at an earlier hour. Evidence of this is to be seen on every hand in the practise of people on Sundays. Whether it is due to indolence or an unconscious striving for maximum comfort is a question the answer to which will not controvert the proposition that the great mass of the people in summer time would prefer to rise and retire later instead of earlier.

Class Thinking. Most persons whose opinion the author has asked on this subject, and probably most persons in this audience, express themselves as in favor of daylight saving. These are people in general whose hours of business are from 9 a.m. to 5 p.m., who have some opportunity for devoting to outdoor recreation leisure time after business hours. This likewise is the class from which advocates of daylight saving come. The subject appears to have received but little comprehensive consideration along national lines. Those favoring and those disfavoring the plan appear to have consulted their own experience and predilection and to have devoted little attention to the other side of the case. The literature as put forward by advocates of daylight saving fails to recognize any disadvantage as accruing to the plan. The benefits to the so-called "laboring class" are stated not by members of that class, but by employers or office workers. The real benefits accruing to a large class of urban dwellers are deprecated by agricultural opponents of the plan, as illustrated by the slogan "Daylight saving means an hour saved for play in the city; it means an hour lost for work in the country." And the very real disadvantages which the measure occasions farmers are disposed of by our metropolitan press in a manner illustrated by the statement that "The farmer seems to have been convinced by some sleight of hand argument."[25]

It is significant to array classes according to their attitude toward daylight daving. It looks something like this—

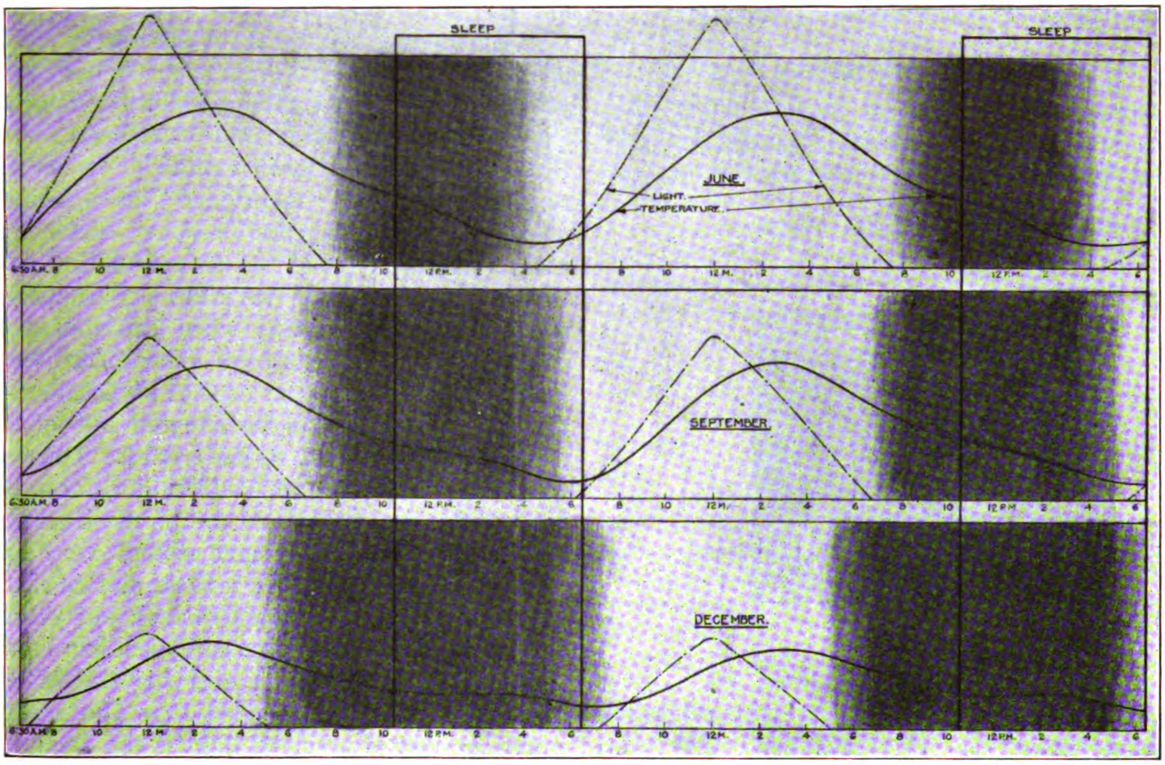


Fig. 12

Favoring	Opposed	Indifferent or Inarticulate
Well-to-do urban and suburban dwellers	Farmers Dairymen	
Officials of the American Federation of Labor	Majority of delegates to convention of American Federation of Labor	Less well-to-do and poor city dwellers
War Garden Commissions	Truck gardeners	
American Medical Association	Miners	

While the foregoing doubtless falls short of full accuracy and completeness, yet it conveys a fairly good idea of the known views on this subject. In the author's judgment there can be little hesitancy in reaching a conclusion after weighing the advantages

and disadvantages. The success, convenience and economy of the producers of food and fuel are of much greater moment to this country than is the added opportunity for outdoor recreation by the class of people which by and large is in a position to secure its own opportunities for recreation.

An unweighted count of urban versus rural populations falls far short of affording a right indication as to the advantages or disadvantages to the country. The urban population is by no means a unit in deriving benefit. Of that part of the urban population which does benefit it is to be said that their convenience or pleasure is not to be weighed on equal terms with a reduction in efficiency in the conduct of an industry which is fundamental to the country's welfare.

Economic Results

Coal Saving. It is estimated in this paper that the saving in coal accomplished through daylight saving is of the order of 495,000 tons per annum. In

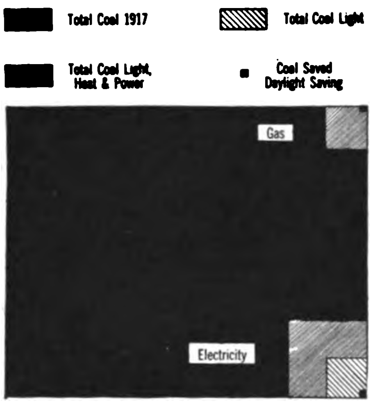


Fig. 13

order to consider this quantity in its proper relation to the coal problem, Fig. 13 is included. The total area of the large rectangle represents the total coal consumption of the country for 1917; the small cross-hatched rectangle in the lower right corner represents the coal estimated to have been consumed in electric lighting. The small black rectangle in the field of this cross-hatched area represents the coal estimated to have been saved in 1918 or 1919 as a result of the reduced use of electric light under daylight saving.

The small cross-hatched area in the upper right-hand corner of the rectangle represents the net coal consumption estimated to have been used by the gas industry in 1917. The small black rectangle in the cross-hatched field represents the saving estimated to have been effected in 1918 through daylight saving. It will thus be seen that the aggregate reduction in the consumption of coal in advanced summer time, while large and important, yet relatively is but a fraction of one per cent of the coal consumption of the country. It may be compared with the figure of 1,250,000 tons usually stated to represent the saving which is effected.[26] The advantage of the Daylight Saving Act as a fuel conservation measure is therefore less than it has been stated to be.

Saving in Expenditure for Artificial Light. Advocates of daylight saving have claimed a one-quarter reduction in cost of artificial light. It would appear probable that their views have been based upon reduction in hours of lighting in the evening which, as shown in Fig. 8, are of the order of 29 per cent. The same diagram shows that in reality the reduction in cost of electric light is only one-quarter of that which might be indicated by this line of reasoning. Estimates of the saving in expenditure of the public for artificial light have ranged from $40,000,000[27] per annum to $100,000,000[8] per annum. In this paper it is shown that the total for electricity and artificial gas is of the order of $19,250,000. This comprehends probably most of the saving which is effected, so that the benefits to the public under this head would appear to be less than has been claimed. If we ignore the reasons previously mentioned for qualifying this statement of saving and assume that the public receives the full benefit of this reduction in expenditure for artificial light, we still have to consider what such a reduction means when distributed over the country. The public's total expenditure for artificial light is only 1 to 1½ per cent of its total expenditure; any saving which can be effected out of this small expenditure is bound to be trivial. Tobacco,[28] soda fountain products[29] and confectionery absorb a larger part of the expenditure of the public than does artificial light. One would not esteem very highly the saving of the expenditure for one or two cigars or one or two ice cream sodas per person per year, yet this is all that is saved in reduced expenditure for artificial light. Therefore without decrying the value of small savings, it may be asserted that the saving to the public in cost of artificial light is too small to be considered as an important factor in weighing the advantages of daylight saving.

On the other hand, when considering economic results, it is necessary to take into account losses suffered by the public as well as saving effected. Some idea of these is obtained by considering interference with agriculture, dairying, and truck gardening. Obviously the estimates of agricultural losses are rough approximations and are probably of a less reliable order than are the estimates in this paper of the effect upon use of artificial light. There appears to be no doubt, however, that the agricultural losses are many times greater than the savings in artificial lighting and it is therefore justifiable to contrast the two estimates in order to emphasize this fact. Thus:

Gain to Public

Estimated savings in electric light	$14,000,000
Estimated savings in gas light	5,250,000
Estimated savings in other forms of artificial light	Probably negligible

Losses to Public

Agricultural losses estimated at	$1,000,000,000
Dairying losses	?
Truck farming losses	?

By those so situated as to be familiar with the facts, it is asserted that daylight saving has made agricultural life less attractive; it has interfered with the "back to the farm" movement; it has probably contributed somewhat toward increasing the cost of living.[30] The economic losses thus involved run so high that the saving in artificial light by comparison sinks into insignificance.

Only one side of the economic phase of daylight saving is presented by advocates of daylight saving. The agricultural disadvantages apparently failed to attract attention when the project was first considered. They proved so serious, however, as to occasion overwhelming adverse sentiment among the members of the House and Senate which led to repeal of the Federal Daylight Saving Act.

Undesirability of Local Action. Whatever the advantages or disadvantages of advanced summer time as a national measure, it would appear that its adoption in particular localities is subject to additional disadvantage. Where such action has been taken the citizens, in the adjustment of industry and of their daily movements, must choose between federal time which will be followed by post office, custom house, railroads, national banks, United States courts, etc., and municipal time which is one hour different and which will be followed by municipal courts, police and fire departments, municipal departments, etc. There is no compulsion upon the public to be guided by either. The attendant confusion, however, is bound to be serious.

Conclusion

It is a fallacy to think that in order for one class to benefit, change must be imposed upon the whole people. It is important to "think nationally." To secure the greatest advantage to the whole people should be the aim.

The very obvious solution of the problem appears to lie in diversification of hours of industry. There are certain classes of people in the cities and suburbs who are in a position to derive benefit from advanced summer time. Without molesting the customs of an entire nation let them undertake an educational propaganda in favor of early rising and early retiring in summer time, together with advancement of the beginning of business hours from say 9 to 8 a.m. It will probably follow that where the advantages of such altered practise seem sufficient, business hours in certain kinds of work will be advanced with consequent diversification of the traction peak, bringing greater comfort to those who must travel in the rush hour. This will avoid local misadjustment of clocks with the attendant confusion which will arise from difference between federal and local time. Education leading to intelligent selection of hours for work, sleep and play is much to be preferred to arbitrary legislation compelling official misrepresentation of time which has the effect needlessly of imposing the will of one class of the population upon another class.

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1. F. A. Annett, Associate Editor *Power*; letter to author December 1st, 1919.

2. P. R. Moses, November 13th, 1919; letter to author.

3. Fifteen per cent increase over 12,500,000,000 kilowatt-hours estimated by author for 1917 in connection with paper "Lighting Curtailment." *Transactions* Illuminating Engineering Society, March 1918, page 111.

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7. "Artificial Gas and By-products in 1915," U. S. Geological Survey.

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8. "An Hour of Light for an Hour of Night." Report of Special Committee of Boston Chamber of Commerce.

9. Report of committee appointed by the Home Department to inquire into social and economic results of the Summer Time Act, 1916.

10. A. N. Gitterman, Chairman War Garden Committee, Borough of Manhattan, New York; letter to author November 14th, 1919.

11. "The War Garden Victorious"—Chas. Lathrop Pack (Lippincott).

12. E. H. Lewinski-Corwin, Executive Secretary, The New York Academy of Medicine.

13. Dr. Chas. Bolduan, Chief Section of Public Health Education; letter to author, November 13th, 1919.

14. Dr. Alex. H. Craig, Secretary American Medical Association, letter to author October 25th, 1919.

15. Dr. F. E. Sondern, proposer of the resolution in letter to author November 15th, 1919.

16. Dr. E. L. Fisk, Director Life Extension Institute; letter to author.

17. For example, Congressman Esch of Wisconsin, Congressional Record June 18-24, 1919, page 1369 stated that among those favoring repeal of the Daylight Saving Act are over 300 farm papers, magazines and organs, every farmers' organization in the United States, and the National Grange.

18. C. W. Burkett, Editor "American Agriculturalist," letter to author November 28, 1919.

19. Collingswood, Editor, *Rural New Yorker*.

20. Atkeson. *Congressional Record*, June 18-24, 1919, page 1369.

21. *Literary Digest*, June 14, 1919, page 17, and letter to the author in which Senator Capper says: "I believe I made a conservative estimate when I put the probable loss at a billion dollars a year."

22. W. W. Hinshaw, letter to press May 28th, 1919.
23. In one instance daylight saving occasioned a strike of miners. This was adjusted by making the hour of beginning work 8 a.m. instead of 7 a.m. Hearing before Committee on H B 3854, pages 25 and 80.
24. Search of the literature and inquiry brought to light only one allegation of reduction in accident rate which was said to have been experienced in the State of Pennsylvania. Further inquiry brought the information that this was incorrect. Letter from John H. Walker, Acting Chief Inspector, Department of Labor and Industry, Harrisburg, Pa., November 25th, 1919.
25. Similar attitude for example in editorial *Greater New York*, (organ of Merchants' Association) March 3, 1919.
26. Marcus M. Marks; letter to the press May 28, 1919, and others.
27. Brunet. Hearing on Senate Bill 1854, May, 1917, page 23.
28. Annual expenditure for tobacco shown to be $490,000,000 in Statistical Abstract, U. S. Department of Commerce, 1914. Editor of *Tobacco* estimates tobacco business to be of the order of $1,000,000,000 per annum.
29. *Soft Drink Journal* April-May, 1918—amount of money estimated to be spent annually by the public at soda fountains, $640,000,000.
30. Congressman Sweet of Iowa, *Congressional Record*, l. c., estimated that daylight saving had increased the cost of living from 5 to 12 per cent on account of reduced production.

A New Form of Vibration Galvanometer

BY P. G. AGNEW

Secretary, American Engineering Standards Committee

Vibration galvanometers are very useful in null measurements, but have not been much used in industrial laboratories on account of their being sensitive to external vibrations and requiring delicate adjustments. The present instrument, which has a sensitivity higher than other forms of the moving-iron type, but less than that of the most sensitive forms of the moving-coil type, has the advantages of sturdiness, quick responsiveness, and freedom from the effects of external vibration. It consists essentially of a fine steel wire, mounted on one pole of a permanent magnet, and so arranged that the free end of the wire may vibrate between the poles of an electromagnet through which the current to be detected passes.

THE vibration galvanometer is a very useful instrument in alternating-current measurements where null methods can be used as, for example, in an almost endless variety of bridge measurements, in various applications of the alternating-current potentiometer, and in testing instrument transformers. As in the case of direct-current galvanometers, there are two general types of vibration galvanometers, the movving-coil type and the moving-iron type. In each type the moving element is mechanically tuned so that its natural period is the same as that of the alternating electromagnetic forces produced by the current to be detected, thus using the principle of resonance to produce a relatively large motion for a very small current.[1]

The reading is usually made by observing the image of an electric lamp filament reflected in a very small mirror attached to the moving system, by means of a telescope, or by a projection upon a screen. When current passes through the instrument the vibration of the moving element causes the image of the filament to appear to broaden out into a band.

It is evident that a vibration galvanometer of either type is simply a specialized form of synchronous motor, the whole mechanical output of which is used in overcoming air friction and elastic hysteresis.

To be presented at the Midwinter Convention, New York, February 20, 1920.

1. For a general discussion of vibration galvanometers, see: Laws' Electrical Measurements, 1917, p. 434; F. Wenner, TRANS. Am. Inst. Elec. Engineers, 31, p. 1243; F. Wenner, *Bull. Bureau of Standards*, 6, p. 347, 1910; A. Campbell, *Proc. Physical Society of London*, 26, p. 120, 1914.

The vibration galvanometer has been used but little in industrial laboratories, its principal use being in physical laboratories, and principally in precision work. The chief reasons for this limited use are that it is easily disturbed by external mechanical vibrations, and that delicate adjustments are necessary. In the present form of instrument these difficulties are greatly reduced. It is not, however, as sensitive as some forms of the moving-coil type.

Principle of Operation. The present instrument is of the moving-iron type. It consists essentially of a fine steel wire, mounted on one pole of a permanent magnet, and so arranged that the free end of the wire may vibrate between the poles of an electromagnet through which the current to be detected passes. If an unmagnetized steel wire, W, is held near the pole of an electromagnet, as in Fig. 1, the end of the wire will be pulled toward the pole of the electromagnet during each half wave of the current flowing in the winding of the electromagnet. That is, the wire will vibrate with twice the frequency of the current. If the wire be magnetized by mounting it on the pole of a permanent magnet, the free end of the wire will be alternately attracted and repelled by the alternating flux of the electromagnet. That is, the wire will vibrate with the same frequency as that of the current. But what is of more importance, the alternating mechanical pull will be very much greater than with an unpolarized wire, since the total flux from the wire is much greater.

The permanent magnet plays the same role in increasing the motion of the wire that the permanent magnet in a telephone receiver does in increasing the

motion of the diaphragm. The total pull varies as B^2, and the change in the pull varies as the change in B^2 resulting from the alternating current. Hence if a given small alternating current produces a change in flux, ΔB, the alternating mechanical pull is proportional to $B \Delta B$, instead of to $\overline{\Delta B^2}$, as it would be if the wire were not polarized by the permanent magnet.

Fig. 2 shows one of the first arrangements experimented with. A small electromagnet is mounted on the inside pole face of the permanent magnet, and the fine wire vibrator on the opposite pole face. The operation is readily seen. During one half-cycle the flux from the pole tip A is slightly strengthened, and that through B is weakened. Hence the vibrator moves toward A. During the next half-cycle the conditions are reversed and the vibrator moves toward B, and so on.

Considering the arrangement as a motor, it is easy to see how the back electromotive force is generated. If the vibrator is moved back and forth by mechanical means, magnetic lines of force from the end of the vibrator move back and forth between A and B, alternately increasing and decreasing the flux in each, and thus generating an alternating electromotive force in the winding.

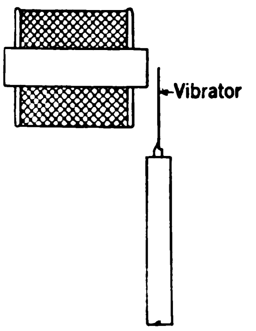

FIG. 1

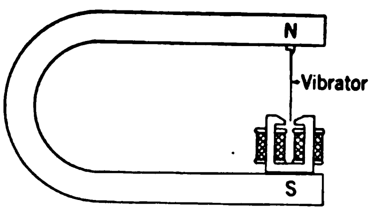

FIG. 2

The vibrator, which is, of course, mechanically tuned so that its period is the same as that of the current to be detected, is observed by a telescope mounted perpendicular to the plane of the paper and focused on the end of the vibrator. In this way a much smaller motion can be detected than is possible with the unaided eye.

During a set of experiments undertaken in order to determine optima of conditions, such as size and shape of electromagnet, shape of pole tips, length of gap, and distance between end of vibrator and pole tips, an interesting observation was made. As a limiting case, the air gap of the electromagnet was reduced to zero by using a closed core as shown in Fig. 3. Even under this condition the device was nearly a tenth as sensitive as with the best arrangement that could be obtained with the same core after it had been sawed so as to form an adjustable gap.

Arrangement for Greatest Sensitivity. Of the many arrangements of parts that have been tried, that which gives the greatest sensitiveness and general convenience of working is shown in Fig. 4.

The electromagnet is placed outside the gap of the permanent magnet, but in a position in which an appreciable amount of flux from the latter passes through the cores of the former. It is to be noted that in principle the arrangement is identical with the earlier one described above, the most important difference in the details of the arrangement being the weaker field to which the core is subjected. The two principal advantages of putting the electromagnet outside are: first, other things being equal, the instrument will

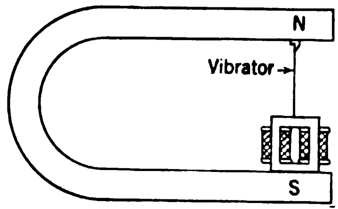

FIG. 3

be most sensitive when the core is working at the point of maximum differential permeability, and the point of maximum differential permeability occurs at very low values of B, (ideally, at $B = O$); second, with low frequency vibrators, which must be of very small diameter, the effect of the strong magnetic field upon the frequency of the vibrator introduces practical difficulties in tuning, since the magnetic forces combine with the elastic force to change the total restoring force, thus changing the frequency. The relative positions of the permanent magnet and the electromagnet were varied systematically, but, as would be expected, the one shown gives the best results.

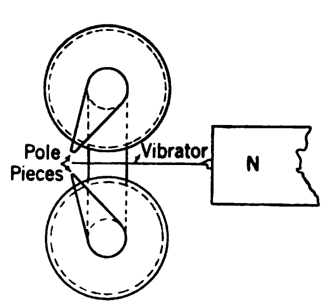

FIG. 4

A high differential permeability is necessary, as just mentioned, for sensitiveness. This means a high initial permeability in the core. Decidedly the best results have been obtained with cores made of good sheet silicon transformer steel. Results seemed to indicate that the sensitiveness varies as the square of the initial permeability instead of as the first power, as was expected, but sufficiently accurate data was not obtained to make certain on this point.

If it is attempted to increase the sensitiveness by bringing the end of the vibrator close to the pole tips, a condition of instability is reached, the vibrator being

pulled over to one or the other of the pole tips. Other practical difficulties arise, such as changes in the tuning of the vibrator. In general, the shorter the gap, the closer can the end of the vibrator be placed to the pole tips without such difficulties being encountered. Considerable changes may be made in length of gap, shape of pole tips, etc., without greatly affecting the maximum working sensitiveness attainable by the various adjustments.

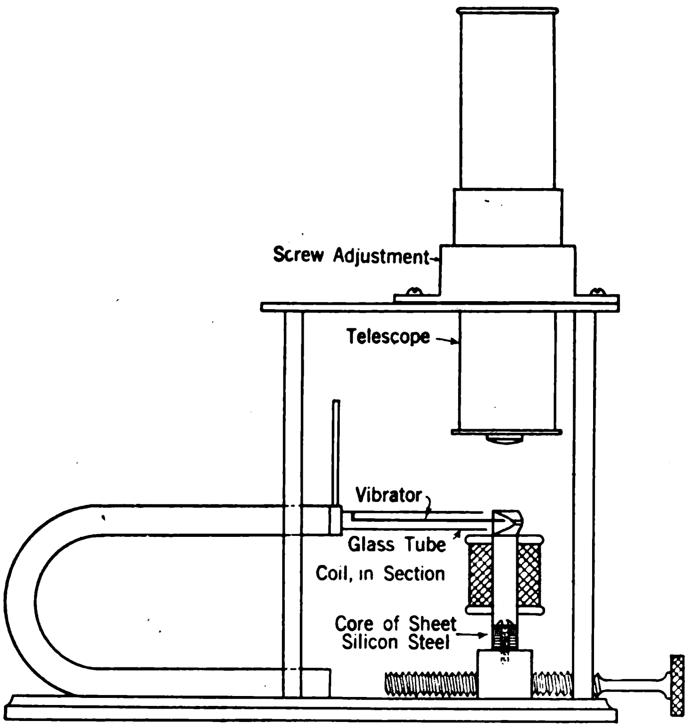

Fig. 5

Generally satisfactory results are obtained with the pole tips brought down in the form of truncated pyramids, the faces being about 2 by 0.5 mm., the short edge being parallel with the plane of vibration of the vibrator, a gap of about 1.5 mm., and the end of the vibrator about 1.5 mm. from the pole tips. An improvement by a factor of 1.5 to 2 may be obtained by setting the pole tips at an angle, as the field is intensified by such an arrangement, (See Fig. 5).

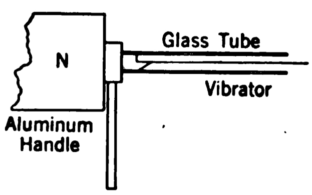

Fig. 6

The Vibrator. The vibrator is mounted on a small base of soft steel, as shown in Fig. 6, and is held in place magnetically, by merely placing the base on the face of the magnet. For convenience in changing vibrators for different frequencies, an aluminum wire is inserted in the base as a handle. For a 60-cycle vibrator a 0.1-mm. wire is convenient, and with this diameter a length of about 33 mm. is required. A 0.04-mm. wire of the same length has a frequency of about 25 cycles. For soft steel wires, the following formula is sufficiently accurate for design purposes:

$$\text{Frequency} = 65{,}000\,\frac{\text{diameter}}{(\text{length})^2}$$

where the dimensions are in centimeters.[2]
For piano wire the constant is higher, about 70,000.

At first it was hoped that such a vibrator might be permanent enough in its frequency to serve the purpose of a frequency meter as well as that of a galvanometer, but it is not feasible, since the actual resonance frequency depends to a small extent upon the position of the vibrator in the magnetic field. Advantage may be taken of this fact, however, to provide a fine adjustment for tuning the vibrator to the exact frequency desired. If an auxiliary small magnet, or better, a pair of such magnets, is placed near the end of the vibrator, the frequency may be changed several per cent, by changing the position of the auxiliary magnet. While it does not readily provide as large a range of adjustment, a more convenient method is to move an iron rod toward or away from one pole of the permanent magnet by a screw motion, as shown in Fig. 4.

If the vibrator is polished, and illuminated by a horizontal beam of light, a sharp line of light may be obtained in the microscope, very similar in appearance to the image of an incandescent filament of moderate brilliancy when viewed in a telescope. Satisfactory readings may also be made by viewing the wire in the ordinary way. In comparing sensitiveness it is convenient to use a vibration just sufficient to make the vibrator appear of double diameter.

It is well to keep the vibrator covered with a very thin film of oil to prevent corrosion. The effect of such a film on the frequency is too small to be at all inconvenient. For many purposes it is convenient to shield the vibrator with a glass tube, as in Fig. 6.

Performance. With a magnifying power of 50 to 100, which has been found satisfactory under working conditions, a motion of the vibrator of five microns is easily visible. With a one-ohm winding an electromotive force of three microvolts can be detected. The construction is such that high resistance coils may easily be wound for high current sensitivity. With a 270-ohm winding the sensitivity is such that a current of 0.05 microampere can readily be detected.

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2. This formula is in the form given by Rayleigh, (Theory of Sound, Vol. 1, art. 171), for the design of the rectangular prong of a tuning fork,

$$N = 84{,}590\ t/l^2$$

where N is the frequency, t the thickness, and l the length.

The chief advantages of the instrument are its sturdiness, the ease of adjustment, its quick responsiveness, and its freedom from the effects of external vibration. In the last characteristic the instrument is an order of magnitude better than any other form of vibration galvanometer with which the author is familiar. Both the freedom from external vibration and the quick responsiveness are due to the relatively large damping by air friction, and the extremely small mass of the moving element. Although the vibration galvanometer depends upon the principle of resonance, an appreciable amount of damping is necessary to give a reasonably quick response to changes in circuit conditions, and the smaller the mass of the moving element, the smaller the amount of energy necessary for a given amplitude, and the more quickly will the requisite amount of energy be supplied from the circuit.

The "resonance range" is about one per cent. That is to say, if the frequency of the current is one per cent above or below the frequency of resonance, the amplitude of vibration will be half as great as at resonance.

The efficiency of the present instrument as a motor is very low, the back electromotive force being only a few per cent of the applied electromotive force. If it should be found possible to increase the electrical efficiency of the device, as a motor, to 50 per cent, the sensitivity would be increased in like ratio, and the instrument would be able to do the work of the most sensitive form of the moving-coil type. Wenner has shown that it is possible to develop an electrical efficiency of over 97 per cent in a vibration galvanometer of the moving-coil type.[3]

The instrument, in various stages of development, has been used in routine testing at the Bureau of Standards for more than three years. While many improvements have been made in detail, a much-to-be-desired radical increase in electrical efficiency has not been accomplished. One possibility is the use of a hardened steel vibrator, permanently magnetized, but a preliminary substitute experiment, in which a soft iron vibrator was surrounded by a magnetizing coil, did not show encouraging results. No attempt has been made to put the vibrator in a vacuum so as to reduce the air friction. It would be necessary to use a fairly high vacuum as the resistance of the air is nearly independent of the pressure down to a pressure of about one mm. of mercury. The sharpness of tuning necessary would increase as the sensitiveness increased, as would also the response to external mechanical disturbances, especially disturbances synchronous with the current. A very promising line of attack which has not been tried is the use of a vibrator made of vacuum process iron, to secure, if possible, a much higher flux in the vibrator.

I am indebted to Mr. J. B. Dempsey for a large part of the experimental work, and for valuable suggestions.

3. Wenner, *Bull. of the Bureau of Standards*, 6, p. 364, 1910.

ENGINEERING AS PROSPERITY INSURANCE

Professor Ely, the economist, has boiled down his discussion of the principles of conservation into half a dozen words that can serve as a rule of action: "*civilization means regard for the future.*" So when I suggest that engineering is prosperity insurance, my choice of words has not been prompted by the professional character of the audience I face but rather by my idea of what the world needs most.

Fortunately I do not have to define my terms; I have only to set forth the way in which the relation between engineering and prosperity impresses me as paralleling in thought the Ely equation—that civilization means regard for the future. Engineering deals in futures; the engineer ever keeps the factor of safety in mind as he works; he is an insurance agent of the first magnitude, even if he does not talk like one.

What we seek for our country, then, is welfare rather than wealth—happiness in fact rather than greatness in name. The members of this Engineers' Club do not need to be more than reminded that "the pursuit of Happiness" was one of the great self-evident truths set forth in that Declaration of Independence, which our fathers assembled here at Philadelphia gave to the world. Nor are we likely ever to overstress the "general welfare" clause of the Constitution as a guiding purpose in our work, whether we serve the public as engineers in private or corporate employ or as engineers on some public pay roll. To strive for well-distributed happiness and to promote the general welfare are aims that belong in the code of the engineer who raises his life work to the level of a contribution to the future.

My conviction is that the future of our nation will be largely what engineers make it, and the surplus that can be paid to other generations of Americans will depend upon what you engineers of today write into that endowment policy, which is to be broad enough to cover Philadelphia, Pennsylvania, and America.

The nation, like the family, can safeguard its future by thrift. We admire Colonial architecture and reproduce it as the fit setting of the modern home; some of us have time and money enough to collect handsome specimens of the stately furniture of Colonial days; all of us may well copy the early American rule of "work and save." Not only did many conspicuous family fortunes have their origin in those early habits of thrift, but our national wealth has accumulated in the same way; as a nation we have produced more than we have consumed. We need now to think in terms of production, simply because without production we cannot consume.

From an address by George Otis Smith, Director, U. S. Geological Survey, before Engineers' Club of Philadelphia, January 20, 1920.

A Method for Separating No-Load Losses in Electrical Machinery

BY CARL J. FECHHEIMER

Designing Engineer, Westinghouse Electric and Mfg. Co.

The method proposed makes use of idle operation of the machine as a motor, the voltage being varied, and speed kept constant. After deducting the armature $I^2 R$ losses from the watts input, the remaining watts are plotted against the voltage. A formula is derived based upon the assumption that the watts are equal to constant windage and friction loss plus core loss which latter varies as a constant power of the voltage. In applying the method, tangents to the curve are drawn at two points, and from the slopes of these tangents, the voltages and watts at these points, the exponent of the core loss curve, the core loss, and the windage and friction may be calculated with the use of the equations derived. An example is given of the close agreement with the test curve in the case of an induction motor; and other examples are cited of close agreement of the core loss and windage and friction losses with the losses measured by means of the usual belted method. The fact is pointed out that in some machines more accurate results are obtainable by means of the proposed method than with the usual belted method.

THE usual method of measuring iron, and friction and windage losses in direct-current and synchronous alternating-current machinery consists in driving by belt from a small direct-current motor and measuring the power input. This method has three disadvantages: (a) The losses in the belt, and the losses in the driving motor are somewhat uncertain, especially the former; (b) the driving motor belt, and possible other auxiliaries require extra floor space, and necessitate equipment which may not be available or difficult of application; and (c) in driving some machines, especially turbo-generators with large stored energy in rotating parts, it is difficult to average with accuracy the current input to the driving motor.[1] The method outlined below may at times necessitate equipment which is not available, or it may require more changes than would warrant its use.

The method is one that has been used frequently. We believe, however, that the method of separation of iron from friction and windage losses is new. It consists in operating the machine idle as a motor, at constant speed, with various voltages impressed across the armature, the watts input to the armature being measured. In the case of a d-c. machine, the excitation and voltages are simultaneously changed so as to maintain constant speed. With synchronous a-c. machines, it is desirable to maintain approximately unity power factor by altering the excitation with the voltage, although slight departure from minimum current will not introduce appreciable errors. With induction machines, the method is the usual idle running saturation curve—the voltage being varied and frequency kept constant. It is advisable to employ integrating instruments for the power, although in some cases indicating instruments will give satisfactory results.

In d-c. and a-c. synchronous machines, the armature $I^2 R$ loss is usually negligible, but in induction machines, this loss is, in general, of appreciable magnitude, and should, therefore, be deducted from the power input.

If we plot volts as abscissas, and power input to the armature[2] (or primary, if an induction motor) as ordinates, the curve will be like that shown in Fig. 1. It is well known that, in many machines, if the laminated iron subject to cyclic changes in flux densities is worked above the knee[3] of the B-H curve, there is stray flux produced which may, by its rate of change, induce electromotive forces in parts external to the laminated iron structure, and such differences of potential may cause currents to circulate, and thereby give rise to by

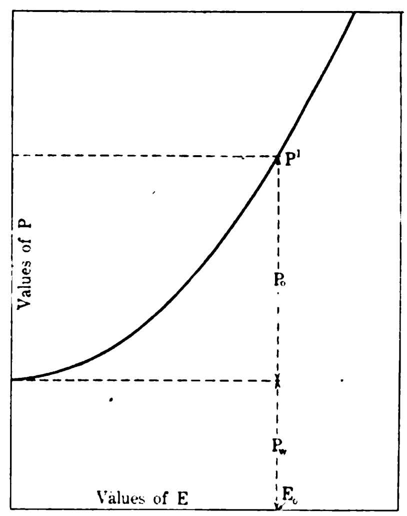

FIG. 1

no means negligible losses. If this condition obtains, the total so-called iron losses augment at a higher rate than ordinarily and we shall, therefore, consider only that part of the loss curve below the point at which the

To be presented at the Midwinter Convention of the A. I. E. E. New York, February 19, 1920.

1. The author believes that the belt friction loss may vary while taking observations when driving large turbo generators, which may introduce an additional error.

2. It is understood that if the $I^2 R$ losses in the armature or primary are appreciable, they must be deducted from the power input.

3. We appreciate that "knee" of curve is liable to be misleading. It appears to us, that with ordinary iron, the departure referred to begins around 12,000 lines per sq. cm. in the core, and 16,500 lines per sq. cm. in the teeth. In giving the method of separation to our Testing Department we have asked them to select the high point at approximately 90 per cent of normal voltage.

high loss gradient begins. We may then write the equation of the curve:

$$P = P_w + P_0\,(E/E_0)^n \qquad (1)$$

Where E = any voltage,

E_0 = voltage below "knee" of B-H curve,

n = constant exponent which indicates the rate at which iron loss increases with voltage,

P_0 = iron loss at voltage E_0,

P_w = friction and windage loss (constant at constant speed),

P = total loss = sum of friction and windage and iron losses.

Or, transposing P_w and taking natural logarithms,

$$\log_e (P - P_w) = \log_e (P_0/E_0)^n + n \log_e E \qquad (2)$$

Differentiating with respect to E, and remembering that $(P_0/E_0)^n$ is a constant,

$$\frac{1}{(P - P_w)}\,\frac{d\,p}{d\,E} = \frac{n}{E} \qquad (3)$$

Or, solving, $$P_w = P - \frac{E}{n}\left(\frac{d\,p}{d\,E}\right) \qquad (4)$$

Select two points[4] on the curve;

For the first:

$$P = P_1 \quad E = E_1 \quad \text{and} \quad \left(\frac{d\,p}{d\,E}\right) = \left(\frac{d\,p}{d\,E}\right)_1;$$

For the second:

$$P = P_2 \quad E = E_2 \quad \text{and} \quad \left(\frac{d\,p}{d\,E}\right) = \left(\frac{d\,p}{d\,E}\right)_2$$

Then,

$$P_w = P_1 - E_1/n\left(\frac{d\,p}{d\,E}\right)_1 = P_2 - E_2/n\left(\frac{d\,p}{d\,E}\right)_2 \qquad (5)$$

Whence

$$n = \frac{E_2\left(\frac{d\,p}{d\,E}\right)_2 - E_1\left(\frac{d\,p}{d\,E}\right)_1}{P_2 - P_1} \qquad (6)$$

In this equation, all quantities in right-hand member may be determined from the curve; $\left(\frac{d\,p}{d\,E}\right)_1$ is the slope of curve at point (1) determined by drawing tangent to curve at that point, etc.

Having found n, we may substitute in (5), and evaluate P_w; or we may solve for P_w without solving for n, thus:

$$P_w = \frac{E_2 P_1\left(\frac{d\,p}{d\,E}\right)_2 - E_1 P_2\left(\frac{d\,p}{d\,E}\right)_1}{E_2\left(\frac{d\,p}{d\,E}\right)_2 - E_1\left(\frac{d\,p}{d\,E}\right)_1} \qquad (7)$$

Finally, if P' = power input at normal voltage, E_0

$$P_0 = P' - P_w \qquad (8)$$

We now have all of the constants in equation (1), and the curve may readily be checked by calculating a number of points.

4. See previous foot-note in regard to "knee" of curve for selection of higher point.

We give below data from a typical test curve of a three-phase induction motor; the equivalent single-phase resistance (1.5 × resistance between terminals) = 0.0438 ohm.

TABLE I

Volts	Amperes	Watts input	I^2R	Watts-I^2R
220	104	3640	475	3165
200	93	3210	380	2830
175	80	2730	280	2450
150	68	2320	202	2118
125	57.5	1940	145	1795
100	47	1640	97	1543
75	36.5	1410	59	1351

We shall plot (Watts − I^2R) against volts as in Fig. 2. If we draw tangent to curve at point E_2 = 185 volts, we obtain $\left(\frac{d\,p}{d\,E}\right)_2$ = 15.15, and P_2 = 2600 watts. Similarly, for point 1, we take E_1 = 85 volts, P_1 = 1420 watts, $\left(\frac{d\,p}{d\,E}\right)_1$ = 7.9.

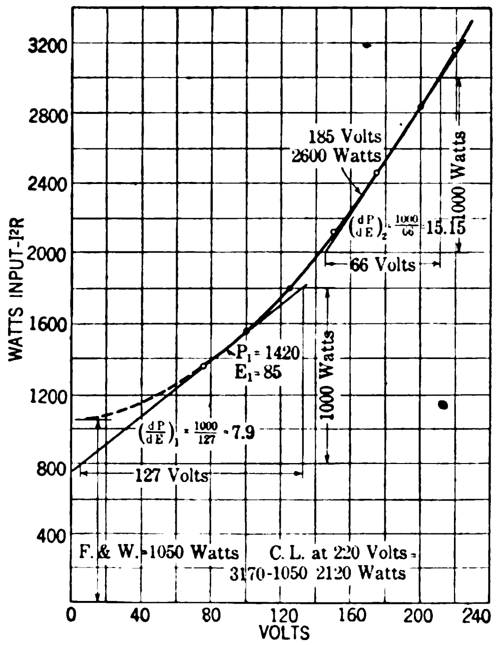

Fig. 2

Substituting in equation (6)

$$n = \frac{185 \times 15.15 - 85 \times 7.9}{2600 - 1420} = 1.81, \text{ the exponent}$$

for iron loss.

Then from equation (5),

$$P_w = 2600 - \frac{185}{1.81} \times 15.15 = 1050 \text{ watts friction}$$

and windage.

From equation (8), $P_0 = 3170 - 1050 = 2120$ watts iron loss at 220 volts. Substituting in equation (1),

$$P = 1050 + 2120\left(\frac{E}{220}\right)^{1.81}$$ is the equation of the curve.[5]

5. In this case, the iron is worked below "saturation" at normal voltage, so that we have taken E_0 to correspond to normal voltage of 220.

We now give the values of watts $- I^2 R$ as determined from test (table I) and those calculated from the equation:

TABLE II

Volts	Watts-I^2R	
	Test	Calculated
220	3165	3170
200	2830	2830
175	2450	2450
150	2118	2092
125	1795	1812
100	1543	1558
75	1351	1350
0	....	1050

It will be found that Fig. 3 is useful in evaluating $E/E_0)^n$ or $(E_0/E)^n$. Plotting K as abscissas and K^n as ordinates on logarithmic paper, gives a straight line which may also be useful.

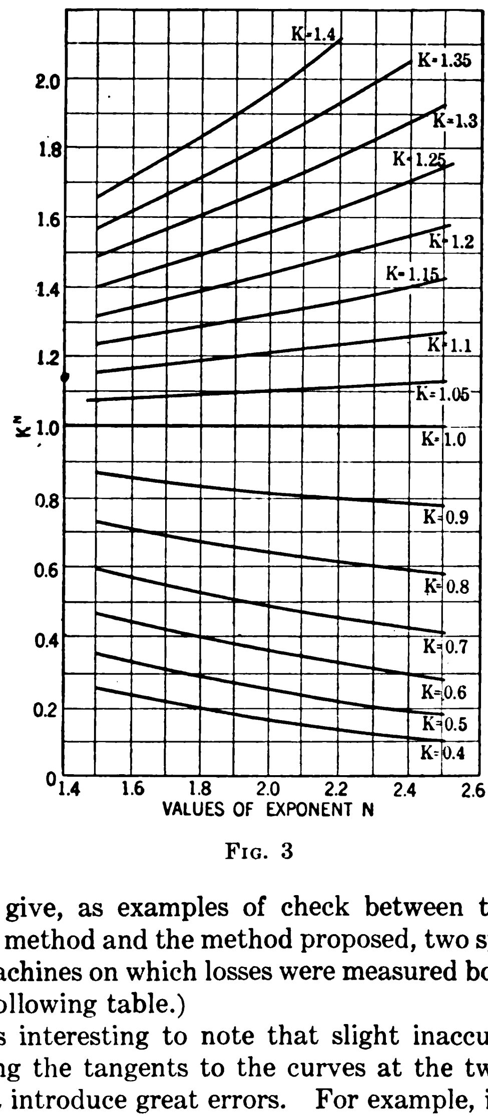

Fig. 3

We give, as examples of check between the usual belted method and the method proposed, two synchronous machines on which losses were measured both ways. (See following table.)

It is interesting to note that slight inaccuracies in drawing the tangents to the curves at the two points do not introduce great errors. For example, in Fig. 2, the tangent at point 2 can be drawn but little, if any, different from that indicated; but at point 1, we might, as extreme with not careful work, draw the tangent so that its slope $\left(\frac{d\,p}{d\,E}\right)$ is 8.3 instead of 7.9. This gives for the exponent "n" 1.774 instead of 1.81 and for P_w 1020 watts instead of 1050 and for P_0 2145 instead of 2120. The difference in friction and windage is thus 3 per cent and in core loss 1.2 per cent. Although this example does not so indicate the exponent "n" usually changes by a larger percentage with slight changes in tangents than does the friction and windage or core loss. Also in the example, the exponent is less than 2, whereas in those synchronous machines which we have investigated, the exponent is slightly above 2.[6]

Maching rating				Kw. core loss at nor. voltage		Kw. friction and wind		
Kv-a.	Volts	R.P.M.	Ph.	Belt	Proposed method	Belt	Proposed method	Remarks
1340	2200	900	3	16.1	16.4	28.	27.6	Part of m-g. set
10,000	4160	1800	3	129.5	124*	143.5	144	Turbo generator

*Machine was warm when making this test, which lowered the iron loss slightly. Machine was started cold for belted test.

In using this method of separation of no load losses, we suggest the advisability of adopting a large scale, especially for the power. For example, if in Fig. 2, had we selected the zero of ordinates to be 1000, we could have doubled the scale and still have plotted the curve on standard cross section paper.

We have obtained quite reliable results with synchronous machines by allowing the integrating wattmeter to run three minutes for each reading. Much depends upon the steadiness of voltage and frequency. It is doubtful whether integrating instruments can be employed to equal advantage with direct current, owing to the fact that such instruments are less reliable than for alternating current.

We have used the method success fully with a 13,500 kv-a. turbo generator, the normal speed of which was 2185 rev. per min. In that case, it was found difficult to obtain consistent data with the ordinary belt method, owing probably, in part, to change in belt loss. We have not experienced difficulty in starting polyphase synchronous machines, having simultaneously brought up to speed the turbo generator and the machine supplying power to it.

While the foregoing application is outlined for separation of iron loss from friction and windage loss, and determination of the equation of the iron loss curve below saturation, it is obvious that it may be applied to any problem in which the general equation is similar in form.

6. Several years ago, the writer observed when plotting on logarithmic paper, core loss curves of synchronous machines (taken by belted method), that the exponent was greater than 2, even below those densities which correspond to beginning of saturation. It would be interesting to have explanations from Institute members.

A Precision Galvanometric Instrument for Measuring Thermoelectric E. M. FS.

BY T. R. HARRISON and PAUL D. FOOTE

Both of the U. S. Bureau of Standards

A new principle has been developed whereby an ordinary millivoltmeter may be converted into an instrument in which the usual errors arising from a variable line resistance are entirely eliminated. The instrument measures true e.m.f. in a simple circuit or if connected across a resistance or network through which a current flows it indicates the potential drop which would have existed had the instrument not been connected. In this respect it functions as a potentiometer, yet it does not operate on the potentiometric principle since it does not require a standard cell (or the equivalent) or an auxiliary battery, the only e.m.f. employed in the adjustment being that of the source measured. No loss in precision of setting results; in fact the adjustment may be readily made to 10 times the scale accuracy. Various wiring diagrams are shown and methods are discussed for constructing instruments of zero temperature coefficient and properly damped. A new deflection potentiometer is described which offers (considerable advantage over the ordinary type for small e.m.fs. in a circuit of variable resistance.

THE maximum e.m.f. developed by a rare-metal thermo-couple is about 15 to 18 millivolts, and that developed by a base-metal couple about 50 to 80 millivolts. To measure such small e.m.fs. accurately by a galvanometric method requires the use of specially constructed millivoltmeters. A millivoltmeter, although graduated to read e.m.f. is fundamentally a current-measuring device. The deflection of the pointer is approximately proportional to the current flowing through the instrument.

If e is the e.m.f. developed by the couple, R_g the resistance of the galvanometer, and R the resistance of the lead wires and couple, the current flowing $= \frac{e}{(R_g + R)}$. Hence in order that a certain deflection correspond to a definite e.m.f., the scale of the instrument must be graduated for a preassigned value of $R_g + R$. Any change in the resistance R from this standard value causes an error in the observed reading of the e.m.f. Such variations may arise from bad contacts, deterioration of the couple, change in depth of immersion, temperature coefficient of lead wires and couple, etc.

In order to minimize the effects of these variations the resistance R_g of the galvanometer is made large compared to that of the line and couple R. This latter resistance in general practise may vary from 1 to 15 ohms. Hence the resistance R_g must be very great in order that changes in R be negligible. The construction of a millivoltmeter having the combined features of high resistance and robustness sufficient to resist the mechanical shocks to which it is necessarily subjected in any industrial plant is an exceedingly difficult problem. The highest resistance ever employed is about 1200 ohms, and instruments are manufactured having a resistance of only 10 ohms. All questions considered, the most satisfactory pivot instruments from the pyrometric standpoint have a resistance of about 5 to 10 ohms per millivolt.

If an instrument having a resistance of 100 ohms is calibrated to read correctly for a line and couple resistance of 2 ohms, and if the resistance of the latter for one of the various reasons mentioned above changes from 2 to 5 ohms, the indicator will read in error by 3 per cent or 30 deg. at 1000 deg. cent. With a 10-ohm indicator the error would be about 20 per cent, or 200 deg. at 1000 deg. cent. Such errors are of serious importance, and are not easily detected unless measurements of the line resistance are frequently made. These measurements require the use of an auxiliary instrument such as a Wheatstone bridge, and then corrections must be applied to the observed reading of the millivoltmeter to take account of the variation in line resistance from the value for which the indicator was standardized.

In the following discussion an instrument is described in which provision is made whereby the total resistance of the circuit may be easily adjusted to the preassigned value for which the scale of the instrument is graduated without requiring the use of any auxiliary instrument or a source of e.m.f. other than that of the couple being measured. Although the instrument was designed primarily for pyrometric purposes, its usefulness is not confined to this field alone.

DESCRIPTION OF COMPENSATED INSTRUMENT

Fig. 1 illustrates the apparatus in a general form. When the instrument is used as a simple temperature indicator, the resistance of the circuit through which the

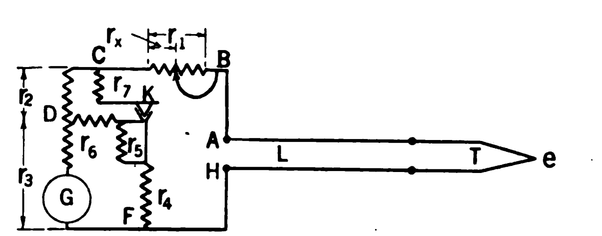

FIG. 1—GENERAL DIAGRAM OF APPARATUS FOR ELIMINATING ERRORS DUE TO UNKNOWN LINE RESISTANCE, FROM WHICH TWO SIMPLE TYPES ARE DERIVED

current from the thermocouple flows is made up as follows: The resistance T of the thermocouple, resistance L of the line or lead wires, a rheostat of resistance r_x which may be adjusted thus altering the resistance of the circuit, a resistance r_2, a resistance r_3 including the resistance of the moving element, r_3 being shunted by

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resistance r_4, r_5, and r_6 connected in series. In addition to these parts of the circuit, arranged as shown in the figure, there is a resistance r_7 connected between points C and K, and a key K which when closed, short circuits r_5, and connects r_4, r_6, and r_7 directly together through the key.

By adjusting one or more of the resistances until a definite relation is obtained between the deflections of the moving element G when the key is open and closed respectively, a definite relation will be established between different resistances of the system. The most convenient relation between the respective deflections is identity, and this relation will be used in the following discussion. In the general case here described, identical readings could be established by adjusting any of the resistances r_x, r_2, r_3, r_4, r_5, r_6, or r_7, but it will appear directly that one desirable method is to adjust r_x, for then the sum of r_x, L, and T is brought to a definite value. The instrument may be so designed that when $r_x + L + T$ = a constant $= r_1$, the total resistance of the circuit is the preassigned value for which the instrument was calibrated. The relation between the resistances may be deduced as follows:

Representing the current flowing through r_3 by i'_3 when the key is open and by i_3 when the key is closed, and the e.m.f. which the couple develops by e, when the key is open we have:

$$\frac{e}{i'_3} = r_1 + r_2 + r_3 + \frac{(r_1 + r_2)\, r_3}{r_4 + r_5 + r_6} \tag{1}$$

When the key is closed we have from Kirchhoff's laws the following seven equations:

$$\begin{aligned}
i_1 - i_2 - i_7 &= 0 \\
i_2 - i_6 - i_3 &= 0 \\
i_3 + i_4 - i_1 &= 0 \\
i_7 + i_6 - i_4 &= 0 \\
i_2 r_2 - e + i_1 r_1 + i_3 r_3 &= 0 \\
i_2 r_2 + i_6 r_6 - i_7 r_7 &= 0 \\
i_3 r_3 - i_4 r_4 - i_6 r_6 &= 0
\end{aligned}$$

in which i with subscript represents the current through the resistance designated by the corresponding subscript.

Solving these equations we obtain:

$$\begin{aligned}
\frac{e}{i_3}\,[r_4\,(1 + r_2/r_6) + r_7\,(1 + r_4/r_6)] \\
= r_7 \left[\frac{(r_1 + r_2)\, r_3}{r_6} + (r_1 + r_2 + r_3)\,(1 + r_4/r_6) \right] \\
+ (r_1 r_3 + r_1 r_4 + r_3 r_4)\,(1 + r_2/r_6) + r_2\,(r_1 + r_4)
\end{aligned} \tag{2}$$

If the deflection of the galvanometer is the same whether the key is open or closed, the current flowing through the galvanometer coil is equal in the two cases ($i'_3 = i_3$) and we may substitute for e/i_3 in (2) the value given for e/i'_3 in (1). Upon simplification of the equation thus obtained we have (3) which is the general conditional equation for the relation between the resistances necessary in order that the deflection of the galvanometer be not altered by closing the key K:

$$r_2 r_4 + \frac{r_3\,(r_1 + r_2)\,(r_2 r_4 + r_4 r_6 - r_5 r_7)}{(r_2 + r_6)\,(r_4 + r_5 + r_6)} = r_1 r_3 + \frac{r_2 r_6\,(r_1 + r_4)}{r_2 + r_6} \tag{3}$$

By assigning certain special values to some of the resistances, equation (3) may be very much simplified.

Making $r_5 = \infty$ (*i. e.* no connection directly across from one switch contact to the other) we obtain:

$$r_2 r_4 - \frac{r_3 r_7\,(r_1 + r_2)}{r_2 + r_6} = r_1 r_3 + \frac{r_2 r_6\,(r_1 + r_4)}{r_2 + r_6} \tag{4}$$

If in addition to making $r_5 = \infty$ we make $r_7 = 0$ the equation reduces to the form:

$$r_2 r_4 = r_1 r_3 + \frac{r_2 r_6\,(r_1 + r_4)}{r_2 + r_6} \tag{5}$$

and finally, upon making $r_6 = 0$ in addition to making $r_5 = \infty$ and $r_7 = 0$, we have the important relation *viz.*:

$$r_2 r_4 = r_1 r_3 \quad \text{or} \quad r_1 = \frac{r_2 r_4}{r_3} \tag{6}$$

This arrangement will be discussed fully below. If we impose the sole condition that $r_5 = 0$, equation (3) reduces to the form:

$$r_1 = \frac{r_2 r_4}{r_6} \tag{7}$$

This is also a very simple form which possesses the advantage that it is independent of the value of r_7, and therefore of contact resistance at the key. For high sensitivity in adjusting r_1 to the proper value, r_7 should be practically zero and r_4 should be also low in order that a large current may flow through r_1 when the key is closed.

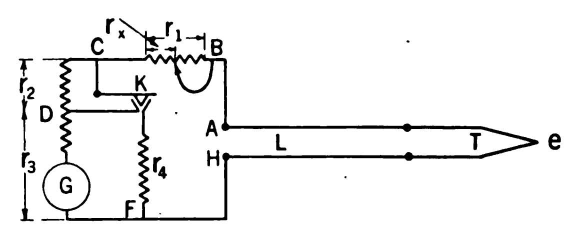


FIG. 2—OPEN SHUNT TYPE FOR HIGH SENSITIVITY, ESPECIALLY SUITABLE FOR THERMOCOUPLES

Fig. 2 shows a diagram of the instrument where $r_5 = \infty$ and $r_6 = r_7 = 0$ as discussed above. The circuit $C\,D\,G\,F$ is an ordinary millivoltmeter or galvanometric indicator of resistance $r_2 + r_3$, the latter resistance including that of the moving element G. In series with this is an adjustable rheostat $C\,B$, the maximum value r_1 of which is chosen equal to the maximum value of the resistance of the line and couple likely to occur in

practise. The galvanometer is calibrated to read correctly when the total resistance R of the circuit has the preassigned value $r_1 + r_2 + r_3$. If in the construction of the instrument $\frac{r_2 r_4}{r_3}$ is made equal to r_1, then when the rheostat $C\,B$ is adjusted to a value r_x such that the deflection of the instrument is the same whether the key is open or closed, the sum of resistances $r_x + L + T$ must equal r_1 and the resistance $r_x + L + T + r_2 + r_3$ of the circuit with the key open must equal the preassigned value $R = r_1 + r_2 + r_3$ for which the scale of the instrument was graduated. Thus it follows, as will be shown more clearly later, that *the instrument measures true e.m.f. in a simple circuit, or if connected across a resistance through which a current flows it will indicate the potential drop which would have existed had the instrument not been connected. In this respect its action is similar to that of a potentiometer. The principle may be also applied to net work conductors, an extension of which leads to a serviceable deflection potentiometer.*

Equation (**6**) may be deduced in a simple manner as follows: If e represents the e.m.f. developed by the couple, e' the potential drop across $D\,F$ when the key is open, and e'' the potential drop across $D\,F$ when the key is closed, we obtain the equations:

$$e' = \frac{e\,r_3}{L + T + r_x + r_2 + r_3} \qquad (\mathbf{8})$$

and

$$e'' = \frac{e\,r_3\,r_4}{(L + T + r_x)(r_3 + r_4) + r_3\,r_4} \qquad (\mathbf{9})$$

If r_x is so adjusted that these two potential drops and hence the deflections of the indicator are the same, we have on equating (**8**) and (**9**):

$$L + T + r_x = \frac{r_2\,r_4}{r_3} = \text{a constant} = r_1 \qquad (\mathbf{10})$$

by construction. Adjustment of the rheostat alters the readings both when the key is open and closed. A simple process for operating the instrument is accordingly as follows:

1. Read the instrument with the key open.
2. Close the key and adjust the rheostat $C\,B$ until the instrument reads approximately the same as in 1.
3. Repeat 1 and 2 if necessary.

Magnification of Errors

By making r_3/r_4 equal to from 5 to 10, the ease with which the proper setting can be obtained is greatly improved. That this is true will be seen from the following consideration.

If the instrument is calibrated to read correctly when the resistances are related according to the equation $r_1/r_2 = r_4/r_3$ and if the rheostat $C\,B$ is out of adjustment by an amount $\delta\,r_1$, the instrument will read in fractional error, when the key is open, by an amount:

$$\frac{\delta\,e'}{e'} = -\frac{\delta\,r_1}{r_1 + r_2 + r_3}$$

and when the key is closed by an amount:

$$\frac{\delta\,e''}{e''} = -\frac{\delta\,r_1}{r_1 + \dfrac{r_3\,r_4}{r_3 + r_4}} \qquad \text{whence}$$

$$\frac{\delta\,e'}{\delta\,e''} = \frac{r_1\,r_3 + r_1\,r_4 + r_3\,r_4}{(r_3 + r_4)(r_1 + r_2 + r_3)} \qquad (\mathbf{11})$$

If $r_1 = r_2$ and $r_3 = r_4$, the above expression simplifies to $\frac{\delta\,e'}{\delta\,e''} = \frac{1}{2}$ or $\delta\,e'' - \delta\,e' = \delta\,e'$. Therefore when $r_3/r_4 = 1$ the difference between the readings will equal the error in the reading when the key is open. If however, r_2/r_1 and r_3/r_4 are made large, say equal to 10, we find $\frac{\delta\,e'}{\delta\,e''} = \frac{1}{11}$ or $\delta\,e'' - \delta\,e' = 10\,\delta\,e'$. Thus if $r_3/r_4 = 10$, the error when the key is open is only 1/11 of the error when the key is closed, or 1/10 of the difference between the readings when the key is open and closed respectively.

In the process for operating the instrument described it is rarely necessary to make a second adjustment when the resistances r_3/r_4 are in as high a ratio as 10. In position 1, the instrument functions as an ordinary galvanometer. The single setting in position 2 reduces the error in the ordinary galvanometer to 1/11 of itself, which is usually sufficient.

The adjustment for the proper external resistance, if desired, can be made with 10 times the precision necessary. Thus, if the galvanometer can be read to 1/10 of a scale division, the line resistance can be set for an error of only 1/100 of a scale division, which is at least 10 times the accuracy possible with any indicating instrument. Hence the factor of variable line resistance which may give rise to very serious errors is easily and accurately controlled by a simple mechanical adjustment.

Multiple Installation

The device is readily applicable to multiple installations of different line resistances. For multiple point recorders and indicators as many resistances $C\,B$ may be employed as there are couples. These may be inexpensive rheostats having a resistance of approximately 15 ohms each, located in each couple line between the couple and the selective switch. These rheostats may be adjusted in the manner described whenever convenient or necessary. The fact that it is not essential to have the extra resistances adjusted to precisely 15 ohms is of great advantage from the

constructional point of view. The instrument may be calibrated for exactly 15 ohms external resistance. If the adjustable resistances accordingly have values of from 16 to 17 ohms, from 1 to 2 ohms more are cut out of the circuit in the process of obtaining a setting than would be the case if resistances of precisely 15 ohms were employed. In either case, however, the final e.m.f. reading is correct.

The following illustrates a suitable proportioning of resistances for a 300 ohm indicator with $r_3/r_4 = 10$:

$$r_1 = 15 \text{ ohms.}$$
$$r_2 = 150 \text{ ohms.}$$
$$r_3 = 135 \text{ ohms.}$$
$$r_4 = 135/10 \text{ ohms.}$$
$$r_1 + r_2 + r_3 = 300 \text{ ohms.}$$

Proper Damping

In designing an instrument of the type discussed above, care must be taken to avoid excessive over damping when the key is closed. The resistances effective in damping are $R = r_1 + r_2 + r_3$ when the key is open and $R_d = r_3 + \dfrac{r_1 r_4}{(r_1 + r_4)}$ when the key is closed. It is evident that R_d is less than R. If we let $K = r_2/r_1 = r_3/r_4$ the following two relations are obtained:

$$r_1 = \frac{R - R_d}{K + \dfrac{R - R_d}{R}} \qquad (\mathbf{a})$$

$$r_3 = r_1 K \frac{R_d}{R - R_d} \qquad (\mathbf{b})$$

For the simple indicator R is known as soon as the scale range is chosen. Suitable values may be selected for r_1 and K and equation (**a**) solved for R_d. If the simple indicator is not seriously overdamped when its total resistance is R_d, this value of R_d is satisfactory, and r_3 may be computed from equation (**b**). The values of r_2 and r_4 follow from K.

If, however, the simple instrument is too sluggish when its total resistance is R_d, the minimum allowable value of R_d may be determined experimentally, and this value, substituted in equation (**a**), determines r_1 with proper choice of K; whence r_2 and r_3.

Temperature Coefficient

In the method so far described, no account has been taken of the temperature coefficient of the instrument. An increase in the temperature of the instrument causes a slight weakening of the springs which tends to allow a given current flowing through the instrument to produce a greater deflection[1]. This tendency is opposed by the effect of a slight decrease in the magnet strength. The effect of the weakening of the springs is almost always in excess of the effect due to the decrease in magnet strength. Thus an instrument becomes more sensitive to current as its temperature rises. In order that a given deflection shall continue to indicate the e.m.f. marked on the scale, the current which this e.m.f. causes to flow through the instrument must decrease with increasing temperature. This requires that the resistance of the circuit increase slightly with increase in temperature. The construction of the instrument is such that its resistance really does so increase. Nearly all of the moving coils used in millivoltmeters are made of copper, the resistance of which increases about 0.4 per cent of its initial value per degree rise in temperature. The majority of instruments require that from 1/13 to 1/40 of the resistance of the galvanometer be composed of copper in order to neutralize the excess of the effect of weakening of springs over decrease in magnet strength and thus give the instrument a zero temperature coefficient.

For an instrument which is constructed with the proper proportion of copper in the circuit, the value of r_1 should be the same whatever the temperature of the instrument. This requires that the value of $\dfrac{r_2 r_4}{r_3}$ also must not vary with temperature. The resistance of r_2 which is of manganin, is practically independent of temperature, but r_3 is composed partly of copper, since it includes the moving element. Therefore in order that r_4/r_3 shall remain constant with changing temperature, r_4 must be composed of the same proportion of copper and manganin as r_3.

Any greater proportion of copper in the instrument than that required as stated above will result in too great a rate of increase of resistance with increase in temperature, and hence the instrument will read too low when its temperature is higher than that at which it was calibrated. Instruments are often made with a greater proportion of copper than is thus required in order to secure a more substantial design suitable for industrial practise and to avoid other difficulties which arise in the construction. One method of making such an instrument read correctly at different room temperatures would be to reduce manually the resistance of the circuit by an amount equal to the increase in resistance of this extra amount of copper in the circuit. The instrument described in the present paper may be arranged so that this compensation is included in the adjustment for variable line resistance without any extra constructional features or manipulation. This is done by allowing the resistance r_4 to have a greater proportion of manganin to copper than r_3. The necessary proportion is found as follows:

Let Q = temperature coefficient of the simple indicator.

P = temperature coefficient of the compensated indicator.

η = temperature coefficient of simple indicator contributed by the copper.

1. See Bureau of Standards Circular No. 20.

ν = temperature coefficient of simple indicator contributed by springs and magnet.

α = temperature coefficient of r_3.

β = temperature coefficient of r_4.

η' = temperature coefficient of compensated indicator contributed by all changes in resistance.

The total temperature coefficient of an indicator is made up of the two parts, the temperature rate of change per ohm of resistance and the combined coefficient of the springs and magnet. Hence for the simple indicator we obtain:

$$Q = \eta + \nu = \frac{\frac{d}{dt}(r_1 + r_2 + r_3)}{r_1 + r_2 + r_3} + \nu$$

$$= \frac{\frac{d\,r_3}{dt}}{r_1 + r_2 + r_3} + \nu \qquad (12)$$

since r_1 and r_2 are constants. For the compensated indicator, however, $r_1 = \frac{r_2 r_4}{r_3}$ is a function of the temperature since both r_3 and r_4 depend upon the temperature. Hence:

$$P = \eta' + \nu = \frac{\frac{d}{dt}(r_1 + r_2 + r_3)}{r_1 + r_2 + r_3} + \nu$$

$$= \frac{\frac{d\,r_1}{dt} + \frac{d\,r_3}{dt}}{r_1 + r_2 + r_3} + \nu$$

$$= \frac{r_1\left(\frac{1}{r_4}\frac{d\,r_4}{dt} - \frac{1}{r_3}\frac{d\,r_3}{dt}\right) + \frac{d\,r_3}{dt}}{r_1 + r_2 + r_3} + \nu \qquad (13)$$

since $$\frac{d\,r_1}{dt} = \frac{r_2 r_4}{r_3}\left(\frac{1}{r_4}\frac{d\,r_4}{dt} - \frac{1}{r_3}\frac{d\,r_3}{dt}\right)$$

$$= r_1\left(\frac{1}{r_4}\frac{d\,r_4}{dt} - \frac{1}{r_3}\frac{d\,r_3}{dt}\right)$$

If in equations (**12**) and (**13**) we substitute

$$\alpha = \frac{1}{r_3}\frac{d\,r_3}{dt} \quad \text{and} \quad \beta = \frac{1}{r_4}\frac{d\,r_4}{dt}$$

we obtain the following:

$$Q = \frac{r_3\,\alpha}{r_1 + r_2 + r_3} + \nu \qquad (12)'$$

$$P = \frac{r_1(\beta - \alpha) + r_3\,\alpha}{r_1 + r_2 + r_3} + \nu \qquad (13)'$$

Whence:

$$P = Q + \frac{r_1(\beta - \alpha)}{r_1 + r_2 + r_3} = \text{temperature coefficient of compensated indicator.} \qquad (14)$$

In order to obtain the condition for an instrument of zero temperature coefficient put $P = 0$ in the above equation, whence:

$$\frac{r_1(\alpha - \beta)}{r_1 + r_2 + r_3} = Q \quad \text{(condition for zero temperature coefficient)} \qquad (15)$$

The coefficients α and β are due to the copper content in the resistances r_3 and r_4. If we assume the temperature coefficient of copper to be 0.004 we obtain:

$$\alpha = \frac{\text{per cent of copper in } r_3}{25{,}000}$$

$$\beta = \frac{\text{per cent of copper in } r_4}{25{,}000}$$

On substituting these values of α and β in equation (**15**) the following equation is obtained for the condition that the compensated indicator have a zero temperature coefficient:

(per cent of copper in r_3) − (per cent of copper in r_4)

$$= 25{,}000\,\frac{r_1 + r_2 + r_3}{r_1}\,Q \qquad (16)$$

If the simple indicator has been so designed that its temperature coefficient is zero, *i. e.* $Q = 0$, equation (**16**) shows that the copper to manganin ratio should be the same in the two resistances r_3 and r_4.

If the simple indicator has a too high copper content so that its temperature coefficient for voltage is positive, *i. e.* $Q > 0$, the experimentally determined value of Q for the simple indicator and the known copper ratio in r_3 may be substituted in equation (**16**) and the proper copper ratio for the shunt r_4 may be readily computed.

Perfect compensation cannot be obtained if $\frac{r_1}{(r_1 + r_2 + r_3)}$ is small and Q is large. The greatest degree of compensation is then secured when r_4 is made entirely of manganin, *i. e.* $\beta = 0$. Hence on making $\beta = 0$, from equation (**15**), we obtain as a condition for the possibility of perfect compensation that:

$$Q \leq \frac{r_1\,\alpha}{r_1 + r_2 + r_3} \qquad (17)$$

Many simple indicators have a temperature coefficient Q which is larger than the maximum value expressed by equation (**17**). In this case the shunt r_4 should be constructed entirely of manganin and the relation between the temperature coefficient of the compensated indicator, P, and that of the simple indicator, Q, readily derived from equations (**12**) and (**13**), is as follows:

$$P = Q\left(1 - 0.004\,\frac{r_1}{r_3 Q}\cdot\frac{\text{ohms of copper in } r_3}{r_1 + r_2 + r_3}\right) \qquad (18)$$

or

$$P = (\eta + \nu)\left(1 - \frac{r_1}{r_3}\,\frac{\eta}{\eta + \nu}\right) \qquad (19)$$

Equation (**19**) is useful for computing directly the value of P on the assumption of a definite value for ν. Usually ν is approximately equal to $-$ 0.0002. We will consider the application of the above equations to the instrument already described.

$$r_1 = 15 \text{ ohms.}$$
$$r_2 = 150 \text{ “}$$
$$r_3 = 135 \text{ “}$$
$$r_4 = 13.5 \text{ “}$$
$$r_1 + r_2 + r_3 = 300 \text{ “}$$

Let $r_3 =$ 50 ohms copper + 85 ohms manganin.

$Q = +\,0.00047$ (assumed to be determined by experiment).

On applying the test given by equation (**17**) it is found that $Q > \dfrac{r_1\,\alpha}{(r_1 + r_2 + r_3)}$. Hence perfect compensation is impossible for the above instrument. By making the shunt entirely of manganin, we obtain on substituting the proper values in equation (**18**):

$$P = (0.00047)\,(0.84) = 0.00040$$

Thus the compensated indicator has a temperature coefficient 16 per cent smaller than that of the simple indicator. The same conclusion follows also from equation (**19**).

Use of the Compensated Millivoltmeter for Measuring Potential Drop

It is at times desirable to measure a small potential drop across a resistance through which a current is flowing. When an ordinary millivoltmeter is employed for this purpose, the potential drop is altered to some lower value which is indicated by the instrument, provided it is graduated to read potential difference at its terminals or at the ends of calibrated lead wires. A similar reading may be obtained with the instrument here described if the rheostat $C\,B$ is set at a marked position such that $r_x = r_1$, since with this adjustment the instrument measures potential drop across its terminals.

Often however, the measurement actually desired is the potential drop which existed across the resistance without the millivoltmeter being connected. This value which may be obtained potentiometrically is also readily measured by the compensated indicator, as will be seen in the following section. When the rheostat $C\,B$ is so adjusted that the deflection of the instrument is the same with the key open or closed, the reading is the potential drop which would exist were the instrument disconnected. One method employed for compensating for irreproducibility of the temperature-e.m.f. relation of different thermocouples of a given type is by the use of shunt and series resistance in the head of the couple.[2]

2. See Foote, Harrison and Fairchild, "Thermoelectric Pyrometry," Pyrometer Symposium, Chicago, 1919.

An ordinary millivoltmeter reads the potential drop existing across the shunt when the instrument is connected. This value depends upon the resistance of the indicator. The reduction in the observed e.m.f. of the couple (potential drop across the shunt) is greater the lower the resistance of the meter. With the compensated indicator however, the ratio of the shunt and series resistances may be definitely adjusted and the instrument, regardless of its resistance, will always indicate, similarly to a potentiometer, that proportion of the e.m.f. e developed by the couple which is represented by the expression

$$e \cdot \frac{\text{shunt resistance}}{(\text{shunt resistance} + \text{series resistance})}\,.$$

Deflection Potentiometer

The compensated indicator may be used as a galvanometer in conjunction with an ordinary potentiometer of low resistance forming a perfectly compensated deflection potentiometer, the compensation being effected by the adjustment of r_x in the manner already described.

This is shown in the following discussion, a special case of which resolves itself to the condition above mentioned in which the instrument may be used to measure the potential drop, which existed before the instrument was connected, over a resistance carrying a current.

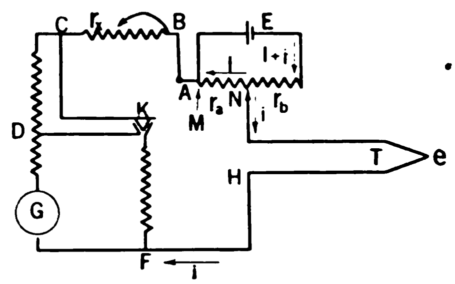


Fig. 3—In Conjunction With any Potentiometer of low Resistance the Instrument Produces a Perfectly Compensated Deflection Potentiometer

Fig. 3 illustrates the use of the instrument as a deflection potentiometer. The potentiometer circuit consists of the battery E and the resistances r_a and r_b the latter including the internal resistance of the battery. When the indicator or galvanometer circuit is broken, for example at A, the potential drop e_1, across r_a is given by equation (**20**):

$$e_1 = \frac{r_a}{r_a + r_b}\,E \qquad (\mathbf{20})$$

Upon connecting the instrument to the potentiometer so that the e.m.f. e of the thermocouple (or any source of e.m.f.) T opposes e_1, the currents flowing through r_a and r_b are unequal and different from the original value. Assume that the currents now flowing are as indicated in the figure, I being the current in r_a, i the current in the indicator or galvanometer circuit,

and $I + i$ the current in r_b. Since the sum of e.m.fs. and potential drops around any closed circuit is zero, the following two equations may be written:

$$E = (r_a + r_b)\, I + r_b\, i \qquad (21)$$

$$e = r_a I - R\, i \qquad (22)$$

in which R equals the resistance of the circuit from M, through $A\ B\ C\ D\ F\ H$ etc. back to N. Substituting the value of I from equation (**21**) in equation (**22**) and subtracting this value of e from the value of e_1, given by equation (**20**) we obtain:

$$e_1 - e = i\left(R + \frac{r_a r_b}{r_a + r_b}\right) \qquad (23)$$

This is the equation of a deflection potentiometer.[3]

If now the resistance r_x is so adjusted that the reading of the instrument is the same whether the key K is closed or open, we have the following relations: Representing the values of i with the key open and closed respectively by i' and i'', we have for the potential drops across $D\ F$ in the two cases, $i'\, r_3$ and $i''\, \dfrac{r_3 r_4}{r_3 + r_4}$.

Equating these we obtain:

$$i'' = i'\, \frac{r_3 + r_4}{r_4} \qquad (24)$$

the condition necessary for equal deflections.

We also have the values R' and R'' for R with the key open and closed respectively.

$$R' = r_x + L + T + r_2 + r_3 \qquad (25)$$

$$R'' = \frac{(r_x + L + T)\,(r_3 + r_4) + r_3 r_4}{r_3 + r_4} \qquad (26)$$

From equation (**23**) it follows that:

$$e_1 - e = i'\left(R' + \frac{r_a r_b}{r_a + r_b}\right) = i''\left(R'' + \frac{r_a r_b}{r_a + r_b}\right)$$

since both e_1 and e are independent of R, e being the e.m.f. of the couple and e_1 being defined by equation (**20**). If the values of R' and R'' from equations (**25**) and (**26**) and the value of i'' in terms of i' from equation (**24**) are substituted in the above equation, we obtain:

$$\frac{r_2 r_4}{r_3} = r_x + L + T + \frac{r_a r_b}{r_a + r_b} \qquad (27)$$

But by the construction of the instrument $r_1 = \dfrac{r_2 r_4}{r_3}$.

Hence from equation (**25**), $R' = \dfrac{r_1 + r_2 + r_3 - r_a r_b}{(r_a + r_b)}$.

If this value of $R = R'$ is substituted in equation (**23**) we obtain:

$$e_1 - e = i\,(r_1 + r_2 + r_3) \qquad (28)$$

3. For general theory and design of deflection potentiometers see Brooks, Bull. Bu. Stds. Vol. 8, 1911, p. 395 (Sci. paper 172) and p. 419 (sci. paper 173).

The compensated indicator is calibrated for a total resistance $r_1 + r_2 + r_3$ so that the current i flowing through the instrument produces a deflection which indicates directly the difference between the e.m.f. e of the couple and the potential drop e_1 existing across r_a with the instrument disconnected. The potentiometer is graduated to read the value of e_1. *Thus when the compensated indicator is used as the galvanometer of an ordinary potentiometer, a deflection potentiometer is obtained which requires no compensation other than that provided by the indicator.*

Evidently the instrument has the disadvantage for continuous use as a deflection potentiometer that a new adjustment is required whenever the dial setting of the potentiometer is changed enough to cause a material difference in the value of $\dfrac{r_a r_b}{(r_a + r_b)}$. In any form of a deflection potentiometer however, changes in the resistance of the couple and leads, unless compensated for, will introduce errors in the galvanometer readings. The ordinary deflection potentiometer may be provided with a rheostat, in series with the couple and galvanometer, which is adjusted until the full scale range is equivalent to one step on the dial. The instrument here described compensates simultaneously for changes in both the couple resistance and potentiometer resistance. This adjustment is simpler than the adjustment for scale sensitivity of the ordinary deflection potentiometer, and hence if the resistance of the couple varies seriously, the new type of deflection potentiometer appears to be the more easily operated.

If in equation (**28**) we let $e = 0$, we obtain the condition which applies when the compensated indicator is connected across a resistance carrying a current. *It follows directly from the reasoning presented above that the instrument indicates the potential drop, e_1, which would exist if the instrument were not connected.*

Calibration of the Compensated Millivoltmeter.

Another useful application of this feature may be employed in calibrating the scale of the indicator. The scheme of connections is the same as that shown in Fig. 3 except that there is no thermocouple T in the circuit. The instrument is connected directly, with the proper polarity to give positive deflections, to the e.m.f. terminals of a potentiometer of sufficiently low resistance that, for all settings, $\dfrac{r_a r_b}{(r_a + r_b)}$ plus the resistance L of any leads employed is not greater than r_1, and the galvanometer terminals of the potentiometer are short-circuited. When the resistance $C\ B$ is so adjusted that the deflection of the indicator is unaltered by depressing the key K, the reading of the potentiometer gives the value of the e.m.f. which should be indicated by the millivoltmeter. The other obvious method of calibrating the instrument in terms of the potential drop across its terminals when the resistance

$r_x = r_1$ is not as simple experimentally, and the former method is applicable at any temperature when the shunt resistance r_4 is constructed with the proper ratio of manganin to copper (see equation **16**) necessary to give a zero temperature coefficient. With the latter method however, the calibration should be made at the temperature for which a definite marked position of the rheostat $C\,B = r_1 = \frac{r_2\,r_4}{r_3}$. This position can be a definite one at only one temperature for a compensated instrument, if the simple indicator has a temperature coefficient. However, the errors likely to arise from not considering this factor are usually of negligible importance.

Use of Compensated Millivoltmeter for Measurement of Potential Drop Across a Network

It follows from the above discussion that the compensated indicator may be used to measure the true potential difference between any two points of a complicated network, existing were the instrument not connected. In this respect the instrument acts as a potentiometer. This is more clearly demonstrated as follows:

In Fig. 4 let r = resistance of network between M and N, excluding branch $M\,P\,N$.

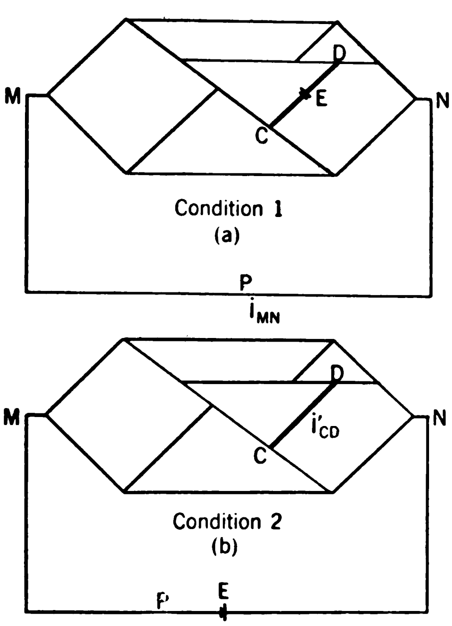


Fig. 4—Showing General Deflection Potentiometer Principle, or Potentiometric Nature of Readings by the Compensated Instrument

R = resistance of branch $M\,P\,N$.

e_2 = potential drop across $M\,N$ for condition 1. Primed letters refer to condition 2, unprimed letters to condition 1.

The current i_{MN} which flows from M to N when an e.m.f. E is introduced in the branch $C\,D$ of the network is equal to the current i'_{CD} which flows from C to D when the same e.m.f. is introduced in the arm $M\,N$[4]. These two conditions are shown by (a) and (b) of Fig. 4.

$$i_{MN} = i'_{CD} \text{ by the above theorem.} \qquad (29)$$

$$i_{MN} = \frac{E}{R + r} \text{ from Ohm's law. Hence:}$$

$$i'_{CD} = \frac{E}{R + r} K \text{ where } K < 1 \text{ is a constant}$$

depending upon the values and the grouping of the separate resistances of the network. Also,

$$i_{MN} = \frac{e_2}{R} = \frac{E}{R + r} K \quad \text{or} \qquad (30)$$

$$e_2 = \frac{E}{1 + r/R} K \qquad (31)$$

When $R = \infty$ let $e_2 = e_1$, whence from equation (**31**) $e_1 = E\,K$. Substituting this value of $K = e_1/E$ in equation (**30**) we obtain:

$$i_{MN} = \frac{e_1}{R + r} \qquad (32)$$

Thus the current flowing in the branch R is equal to the potential drop across $M\,N$ with the branch circuit open divided by the total resistance of the circuit.

Suppose the branch circuit to be the compensated indicator. The current flowing through the instrument is given by equation (**32**), and the two values R' and R'' of R (key open and closed) are expressed by equations (**25**) and (**26**). Hence:

$$\text{Key open } i' = \frac{e_1}{r_x + L + T + r_2 + r_3 + r}$$

$$\text{Key closed } i'' = \frac{e_1}{(r_x + L + T) + \dfrac{r_3\,r_4}{r_3 + r_4} + r}$$

If r_x is adjusted for equal deflections with the key open and closed we may substitute these values of i' and i'' in equation (**24**) and obtain:

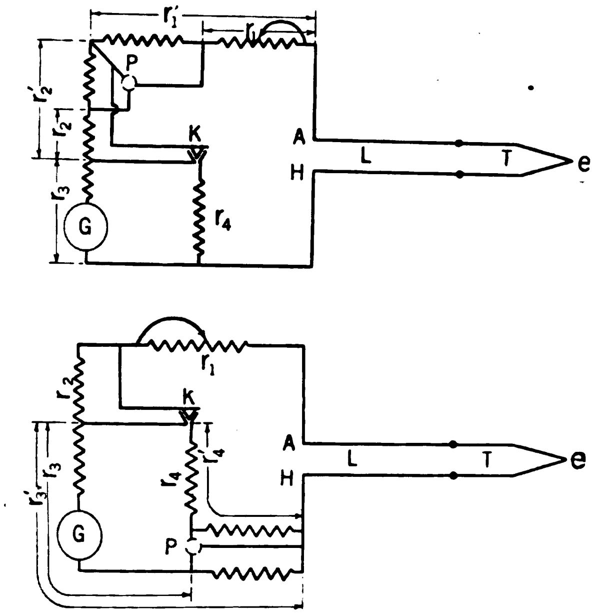
$$\frac{r_2\,r_4}{r_3} = r_x + L + T + r = r_1 \; (33) \text{ as in equation } (27)$$

Thus with the key open $e_1 = i'\,(r_1 + r_2 + r_3)$. The instrument is calibrated for the total resistance $(r_1 + r_2 + r_3)$ so that the current i' produces a deflection which indicates directly the true potential difference e_1 existing between any two points of a net work. If there are several e.m.fs. E_1, E_2, etc. in different arms of the net work, it readily follows that the instrument still measures the true potential drop, on open external circuit, between any two points to which it is connected.

4. Jeans Math. Theory of Elec. and Mag. 3rd Ed. p. 327. See also Maxwell.

Double Scale Range

Figs. 5 and 6 illustrate modifications of the simple design shown in Fig. 2 to permit the use of two different e.m.f scales. In Fig. 5 the resistances r_1 and r_2 are increased in the same ratio and by such an amount that the total resistance $r_1' + r_2' + r_3$ gives the desired sensitivity for the high range scale. Thus $r_1/r_2 = r_1'/r_2' = r_4/r_3$ and the factor for the magnification of errors is the same with either range. With the plug in at P, $r_1' - r_1$ and $r_2' - r_2$ are short-circuited and the instrument operates on the low range scale. With the plug out r_1 is increased by the fixed resistance $r_1' - r_1$ and r_2 is changed to r_2', and the instrument operates on the high range scale.



Figs. 5 and 6—Double Range Instruments, Compensated in Either Range

In the design shown by Fig. 6 the resistances r_3 and r_4 are increased in a similar manner such that $r_1/r_2 = r_3/r_4 = r_3'/r_4'$.

Use of an Unadjustable Value for r_1

In the foregoing discussion adjustment of the resistance r_1, which consists in part of the line and couple, has been considered. As has already been pointed out, if any of the four resistances in Fig. 2 is adjusted to give equal galvanometer deflections with the key open and closed, the relation $r_1/r_2 = r_4/r_3$ will be established.

In Fig. 7, r_3 is made equal to r_4, and its value is chosen such that the instrument reads correctly when the total resistance of the circuit equals $r_2 + r_3 + r_x$ where $r_2 + r_x$ is the total resistance of the rheostat. With this arrangement $r_1 = L + T$. When switch S is in position B', adjustment for equal deflections makes $r_1 = r_2$, (since $r_4 = r_3$). After this adjustment switch S is thrown into position B, and the resistance of the circuit, $L + T + r_x + r_3$ equals $r_2 + r_x + r_3$, the resistance for which the instrument reads correctly. The process of adjusting is to close the key K and read the instrument, open the key and adjust the rheostat until the instrument shows the same deflection, and then throw S into the opposite position. The method has the advantage that the reading with the key closed is independent of the setting of the rheostat; therefore, when adjusting the rheostat with the key open the reading to which the instrument should be brought is

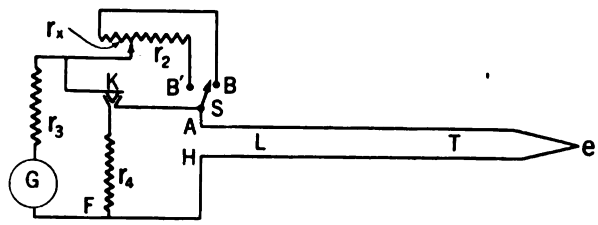


Fig. 7—Modification of Fig. 2

accurately known. It is immaterial which way switch S is set during the adjustment, provided its position is changed after the adjustment has been made. Three disadvantages will be noted. (1) Since $r_3 = r_4$, there is no multiplication of errors in setting; (2) an extra switch S is required, and this switch must be operated each time an adjustment is made; (3) any contact resistance existing in the rheostat will alter the final resistance of the circuit by double this amount. Such contact resistances constitute no error in the instrument shown in Fig. 2.

Fig. 8 shows a design, somewhat similar to that illustrated by Fig. 7, which is modified to give a multiplication of errors on setting. Resistance r_4 is made equal to r_3/m, where m is any desirable factor for

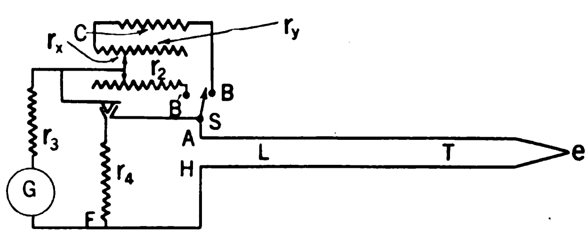


Fig. 8—Modification of Fig. 7 Arranged for Accuracy of Adjustment

multiplication of errors. The total resistance $r_x + r_y$ of the upper rheostat is made equal to the maximum allowable line and couple resistance. The total resistance of the rheostat of which r_2 is part is made equal to $m\ (r_x + r_y)$. Adjustment for equal deflections with switch S at B' makes $r_2 = m\ (L + T)$, whence, since the two rheostats are adjusted simultaneously, $r_y = L + T$. This is removed from the circuit upon setting switch S in working position B. Resistance r_3 in Fig. 8 is made less than r_3 in Fig. 7, in order to compensate for a higher value of r_2. Resistance C is added to bring the total resistance of the circuit in the operating position up to the proper value.

In Fig. 9 the resistance r_4 is adjustable. By construction r_2 is made equal to r_3. Switch S is closed and r_4 is adjusted until equal deflections of the galvanometer are established. This makes $r_4 = r_1 = L + T$. Opening switch S adds resistance r_x to the circuit, making the total resistance equal to $r_2 + r_3 + x$, the resistance for which the instrument is calibrated. With S closed and K open the reading is independent of the setting of the rheostat. This reading is noted. With switches K

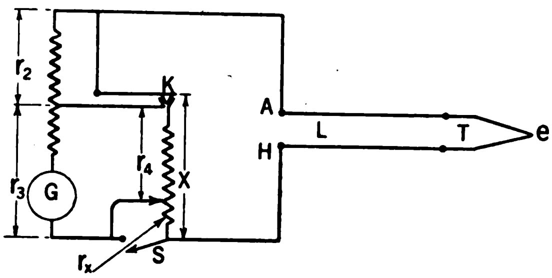


FIG. 9—ANOTHER MODIFICATION OF FIG. 2

and S closed r_4 is adjusted until the reading is the same as that determined above. The factor m increases rapidly as resistance $L + T\ (= r_1)$ decreases. Its value is given by the expression $m = \dfrac{r_2 + r_3 + x}{2\, r_4\, (1 + r_4/r_3)}$.

COMPENSATED MILLIVOLTMETER WITH $r_5 = 0$

The circuit for an instrument designed according to equation (7) in which $r_5 = 0$ is shown by Fig. 10. The instrument possesses many advantages, one of these being the complete elimination of objectionable effects

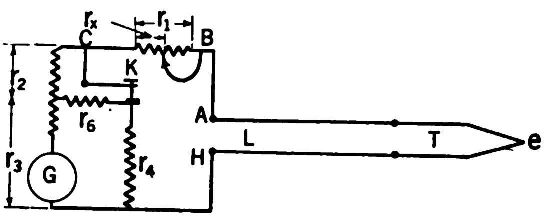


FIG. 10—CLOSED SHUNT TYPE OF COMPENSATING INDICATOR

of contact resistances. It is further possible to compensate for temperature coefficient by the well known Swinburne[5] method, to obtain any desirable magnification ratio for errors, and to secure an instrument which is satisfactorily damped either with the key open or closed. Where a desirable magnification ratio cannot be otherwise obtained a battery may be inserted between c and K, Fig. 10. The proportioning of the various resistances is illustrated by the following discussion:

Let i' = current through the galvanometer coil necessary to produce full scale deflection.

e' = maximum e.m.f. measured = highest scale reading.

5. Hallo and Land, Electric and magnetic measurements and measuring instruments, 1906, p. 260.

R_g = resistance of the moving copper coil.

m = magnification ratio for errors $\left(\dfrac{\text{key closed}}{\text{key open}}\right)$.

R_d = proper damping resistance.

Hence:

$$\frac{(r_3 + r_4 + r_6)\,(r_1 + r_2)}{r_4 + r_6} + r_3 = e'/i' = S \qquad \text{(Scale range)} \quad (34)$$

Equation (**34**) is the condition for scale range such that an e.m.f. e' produces a full scale deflection.

$$r_1/r_2 = r_4/r_6 \qquad \text{(Key adjustment)} \quad (35)$$

Equation (**35**) is deduced as shown by equation (**7**) and expresses the condition that the deflection of the galvanometer is the same with the key K open or closed.

$$r_1 + r_2 = (r_4 + r_6)\,\frac{R_g}{r_3 - R_g} \qquad \text{(Temperature compensation)} \quad (36)$$

Equation (**36**) imposes the condition for temperature compensation by the Swinburne method. The resistances r_4 and r_6 must be of copper.

$$\frac{1}{m} = \frac{\delta\, e'}{\delta\, e''} = \frac{r_1 + r_4 - r_4 \dfrac{r_4}{r_3 + r_4 + \dfrac{r_2\, r_6}{r_2 + r_6}}}{r_1 + r_2 + \dfrac{r_3\,(r_4 + r_6)}{r_3 + r_4 + r_6}} \qquad \text{(Errors)} \quad (37)$$

Equation (**37**) shows the relation between the error in a setting with the key open and with the key closed. This is derived in a manner similar to that employed in the discussion of Fig. 2.

$$R_d = r_3 + \frac{(r_1 + r_2)\,(r_4 + r_6)}{r_1 + r_2 + r_4 + r_6} = r_3 + \frac{(r_1 + r_2)\, r_4}{r_1 + r_4} \qquad \text{(Damping)} \quad (38)$$

Equation (**38**) gives the total resistance of the galvanometer circuit with the key open. This should equal the proper damping resistance which is slightly greater than the critical damping resistance. It will be noted that when the resistance r_x is adjusted for identical deflections with the key open and closed the resistance effective in damping is the same with the key in either position, and hence if the instrument is properly damped with the key open, it will be properly damped with the key closed.

The above 5 equations serve to determine the 5 variables r_1, r_2, r_3, r_4, and r_6. However, the condition for proper damping, equation (**38**), need not be satisfied exactly. The behavior of an instrument usually allows considerable tolerance in the value of R_d. Hence in order to obtain wide limits for construction, the first four equations may be solved as indeterminants and the best values of the resistances consistent with a suitable damping resistance may be chosen for the final design. The third term in the numerator of the

right hand member of equation (**37**) is usually small. In place of equation (**37**) we shall assume the following relation:

$$\frac{1}{K} = \frac{r_1 + r_4}{r_1 + r_2 + \dfrac{r_3\,(r_4 + r_6)}{r_3 + r_4 + r_6}} \qquad (\mathbf{39})$$

The solution of equations (**34**), (**35**), (**36**), and (**39**) is as follows:

$$r_1 = \frac{R_g\,S}{K\,r_3\left[\,1 - \dfrac{r_3\,R_g}{(r_3 - R_g)\,(S - r_3)}\right]} \qquad (\mathbf{40})$$

$$r_2 = S - r_1 - r_3 - \frac{r_3\,R_g}{r_3 - R_g} \qquad (\mathbf{41})$$

$$r_4 = \frac{r_1\,(r_3 - R_g)}{R_g} \qquad (\mathbf{42})$$

$$r_6 = \frac{r_2\,r_4}{r_1} \qquad (\mathbf{43})$$

The following example illustrates the method of applying the above equations: It is desired to convert an ordinary millivoltmeter, scale range 0 – 15 millivolts into the above compensated instrument having a scale range 0 – 60 millivolts. The resistance of the simple indicator is 250 ohms of which the copper content $R_g = 60$ ohms. The instrument if suitably designed is accordingly properly damped on $R_d = 250$ ohms. Since the scale range is to be increased by the factor 4, the value of $S = 4 \times 250 = 1000$ ohms. Let $K = 10$. This is closely equal to m the magnification ratio for sensibility to changes in r_1 with the key closed. For various assumed values of r_3 compute r_1 from equation (**40**). For corresponding values of r_3 and r_1 compute r_2 from equation(**41**). Similarly for equations (**42**) and (**43**).

The following table illustrates the results thus obtained:

Values of Resistances for $r_5 = 0$

r_3	r_1	r_2	r_4	r_6	$r_3 + \frac{(r_1 + r_2)\,(r_4 + r_6)}{r_1 + r_2 + r_4 + r_6}$	m
65	15.3	140	1.27	11.7	77	10.0
70	47	463	7.84	77.3	143	
80	55.5	626	18.5	208.5	250	10.2
90	53.5	676	26.7	338	333	
100	50	700	33.3	466	400	10.3
200	26.8	688	62.5	1605	700	
300	17.85	607	71.4	2428	800	10.7

Any of the above designs gives a millivoltmeter of scale range 0 – 60 millivolts, compensation for temperature coefficient by the Swinburne method and complete elimination of the error due to uncertain line drop. The values corresponding to $r_3 = 80$ furnish the proper damping, 250 ohms, characteristic of the particular instrument selected. If we substitute the values of the various resistances in equation (**37**) we obtain $m = 10.2$ which gives the ratio of sensitivities with the key closed and open.

If equations (**40**) to (**43**) do not furnish satisfactory values for the resistances with a suitable choice for K, equation (**36**) may be omitted and equations (**34**), (**35**) and (**39**) may be solved indeterminately similar to the manner above outlined. If the final choice of values for the various resistances results in an excessive temperature coefficient of the compensated instrument, this can be minimized by making r_4 and r_6 of unequal temperature coefficients, thus allowing the adjustment of r_1 to vary with the temperature as was done with the instrument illustrated by Fig. 2.[2]

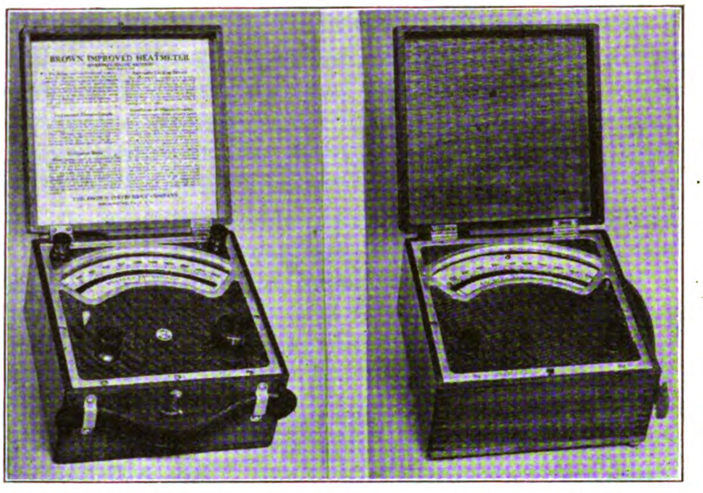


FIG. 11—COMPARISON OF INSTRUMENTS WITH AND WITHOUT COMPENSATING DEVICE. COMPENSATED INSTRUMENT SHOWN ON LEFT

The instrument on the right in Fig. 11 is an ordinary millivoltmeter. The other instrument is the compensated millivoltmeter constructed according to the wiring diagram shown in Fig. 2. It will be noted that the additional wiring requires no alteration in the size of the finished instrument.

SUMMARY

A new principle has been developed whereby an ordinary millivoltmeter may be converted into an instrument in which the usual errors arising from a variable line resistance are entirely eliminated. All of the several modifications described afford some simple means by which the total resistance of the galvano-

6 This method of treatment has recently been developed more fully and will appear in an early issue of the *Journal Wash. Acad. of Sci.* In this treatment the compensation for coefficient of springs and magnet is considered. This condition is more easily satisfied than is that required by eq. (**36**). This method is useful in making low range instruments.

meter circuit, internal and external, is adjusted to a preassigned value for which the scale of the instrument is calibrated. In one form now manufactured the instrument consists of an adjustable resistance r_x in series with the moving coil and swamping resistance of the millivoltmeter. On depressing a key part, r_2, of the swamping resistance is short-circuited and the remaining part together with the moving coil, r_3, is shunted by a resistance r_4. The instrument is calibrated in terms of the potential drop across its terminals for a maximum value of $r_x = r_1$. In the construction the resistances are proportioned according to the relation $r_2 r_4 = r_1 r_3$. If the resistance r_x is so adjusted that the deflection of the pointer is unchanged by depressing the key it is shown that the total resistance of the circuit is that for which the instrument is calibrated, the sum of r_x and all external resistance being thus made equal to r_1. Hence it follows that the instrument measures true e.m.f. in a simple circuit, or if connected across a resistance or network through which a current flows it indicates the potential drop which would have existed had the instrument not been connected. In this respect it functions as a potentiometer, yet it does not operate on the potentiometric principle since it does not require a standard cell or an auxiliary battery, the only e.m.f. employed in the adjustment being that of source measured.

By constructing r_3/r_4 equal to from 5 to 10 it is possible to adjust r_x with 5 to 10 times the precison necessary. Thus if the galvanometer can be read to 1/10 of a scale division the line resistance may be adjusted with a precision equivalent to 1/100 of a scale division, which is at least 10 times the accuracy possible with any indicating instrument. This principle of magnification of errors greatly facilitates the proper adjustment of r_x. By varying the copper to manganin ratio in r_4 it is possible to produce a compensated instrument of zero temperature coefficient from a millivoltmeter having an excessive copper content.

The instrument may be used as a galvanometer with an ordinary potentiometer, forming a deflection potentiometer which requires no compensation other than that provided by the indicator. Such an instrument is especially serviceable in thermocouple work.

The compensated millivoltmeter may be used in multiple installations of thermocouples having different line resistances, as many resistances r_x being employed as there are couples. These may be inexpensive rheostats, one located in each line between the couple and selective switch, and still the accuracy of adjustment will be as high as though precision rheostats were employed.

Methods are described for constructing instruments of double scale range with compensation in both ranges.

Specifications are given for an instrument which compensates for line resistance, which has a zero temperature coefficient, and which is properly damped either with the key closed or open.

NEW WIRELESS PHONE CARRIES 900 MILES

Announcement has just been made that during the past month wireless telephone conversations have been carried on between Ossining, N. Y. and Chicago, a distance of about 900 miles, as well as with cities in Indiana and Ohio, with the use of a small aerial, a 375-meter wave length, and a power of 1/3 of a kilowatt. Mr R. F. Gowan, engineer of the De Forest radio station at Ossining, who made the experiments is quoted in the New York *Times*, as follows:

"The effect of the new circuit is to render the voice transmission much clearer, while the use of a new type of glass permits of much greater input circuit in the development of the wireless power.

"It is further interesting to note that all my experiments are being conducted on a comparatively low wave length—that is to say, the special amateur wave lengths permitted by the Government regulations. In addition, the experiments show that the distance between Ossining and Chicago is covered with only one-third of the energy of which the De Forest oscillion or oscillating audion is capable of developing. In other words, with only one-third kilowatt of input energy in a single tube we are enabled to talk without wires from New York to Chicago.

"We have been able to talk over a distance of 900 miles, but we have today reached the commercial development of the wireless telephone under all conditions, I should say, for a distance of at least 300 miles, that is, a service identical with the long distance telephone.

"The experiments in question have been conducted night after night since Jan. 1, and through the most severe static interference. There has also been tremendous interference from other stations, and yet in spite of all this when I picked up the telephone transmitting apparatus at Ossining and spoke into it, just as any one might speak into the ordinary telephone, I discovered that my voice was being distinctly heard first of all in the little town of St. Mary's, Ohio. The radio amateur at St. Mary's, it seems, was at that time picking up local dots and dashes, and when he heard this voice from out of the air, the sending location of which was reported to be Ossining, N. Y., he was, to say the least, somewhat startled. He immediately answered by sending me a telegraph inquiry which I distinctly heard in my own receiving apparatus. I then repeated my conversation to him and asked him to confirm the conversation immediately by letter. This he did."

In the same way conversations were picked up by amateur stations in Salem, Ohio, Gaffney, S. C., Wakefield, Mass. and Chicago. In all cases the messages were received unexpectedly and without previous arrangement.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

EIGHTH MIDWINTER CONVENTION

FEBRUARY 18-20, 1920

The Eighth Annual Midwinter Convention of the American Institute of Electrical Engineers will be held February 18-20, 1920, in the Engineering Societies Building, 33 West 39th Street, New York.

Wednesday, February 18

The Registration Bureau will be located in the Foyer of the building and will open in the morning for the registration of members and guests.

On Wednesday morning there will be a meeting of the Board of Directors of the Institute.

On Wednesday afternoon the alternative is offered of engaging in one of the numerous trips to points of engineering interest, listed in detail elsewhere in this announcement, or of accepting the invitation of the American Institute of Mining and Metallurgical Engineers to attend the final session of its convention in the Engineering Societies Building. At this meeting papers will be presented on the Physical Properties of Iron, Steel and Their Alloys.

Wednesday evening there will be a technical session, opened by an address by President Calvert Townley, followed by the presentation of papers by Preston S. Millar, W. S. Gorsuch and E. J. Cheney.

Thursday, February 19

On Thursday morning a symposium will be presented on "Economical Supply of Electric Power for the Industries and Railroads of the Northeast Atlantic Seaboard." Reference to this Symposium will be found on page 179 of this issue of the JOURNAL.

On Thursday afternoon parallel sessions will be held in the Auditorium and in Room 1, 5th Floor. Papers will be presented by J. H. Bell, G. A. Campbell, R. M. Foster, C. J. Fechheimer, A. I. Ellis, B. W. St. Clair, P. E. Klopsteg and A. L. Loomis.

On Thursday evening there will be a Dinner-Dance at the Hotel Astor for members and guests in attendance at the Convention. Particulars in regard to this function will be found under the heading Entertainment.

Friday, February 20

On Friday two technical sessions will be held, both under the auspices of the Instruments and Measurements Committee.

At the morning session three papers will be presented by P. G. Agnew, J. R. Harrison and P. D. Foote, and J. B. Whitehead and T. Isshiki.

In the afternoon two papers will be presented by A. E. Kennelly, R. N. Hunter and A. A. Prior, and H. B. Brooks.

PROGRAM

Wednesday Morning, February 18

Registration Bureau opens.
Board of Directors Meeting, 10:30 a.m.

Wednesday Afternoon, February 18

AUDITORIUM 2:30 P. M.

Participation in meeting with American Institute of Mining and Metallurgical Engineers.
Alternative: Visits to points of Engineering Interest.

Wednesday Evening, February 18

AUDITORIUM 8:15 P. M.

Address—by the President Calvert Townley.

1. *Daylight Saving*, by Preston S. Millar, Manager Electrical Testing Laboratories. New York.
2. *Essential Statistics for the General Comparison of Steam Power Plant Performance*, by W. S. Gorsuch, Engineer Economics, Interborough Rapid Transit Co., New York.
3. *Standard Graphic Symbols*, by E. J. Cheney, Chief of Division of Heat, Light and Power, Public Service Commission, Albany, N. Y.

Thursday Morning, February 19

ROOM NO. 1, 5TH FLOOR, 10:30 A. M.

4. *Economical Supply of Electric Power for the Industries and the Railroads of the Northeast Atlantic Seaboard*, A Symposium.

Thursday Afternoon, February 19

Parallel Sessions:

AUDITORIUM, 2:30 P.M.

5. *Printing Telegraph Systems*, by J. H. Bell, Telegraph Engineer, Western Electric Co.
6. *Maximum Output Networks for Telephone Substation and Repeater Circuits*, by G. A. Campbell, Research Engineer, American Telephone and Telegraph Co., and Ronald M. Foster, Assistant to Research Engineer, American Telephone and Telegraph Co.

ROOM NO. 1, 5TH FLOOR, 2:30 P.M.

7. *A Method of Separating No-Load Losses in Electrical Machinery*, By C. J. Fechheimer, Designing Engineer, Westinghouse Electric & Mfg. Co.
8. *Inherent Regulation of D-C. Circuits*, by A. L. Ellis, Thomson Laboratory, General Electric Co. and B. W. St. Clair, Standardizing Laboratories, G. E. Co., Lynn, Mass.
9. *Measurements of Projectile Velocities*, by P. E. Klopsteg, Physicist, Leeds & Northrup Co., and A. L. Loomis, formerly Major Ordnance Dept., U. S. A.

Thursday Evening, February 19

Hotel Astor, 7:00 p.m.

Dinner Dance at Hotel Astor. For details see item *Entertainment* following.

Friday Morning, February 20

Room 1, 5th Floor, 10:30 a.m.

10. *A new Form of Vibration Galvanometer*, by P. G. Agnew, Secretary American Engineering Standards Committee.
11. *Precision Galvanometer for Measuring Thermo E. M. Fs.* T. R. Harrison and P. D. Foote, both of U. S. Bureau of Standards.
12. *Notes on Synchronous Commutators*, by J. B. Whitehead, Professor of Electrical Engineering, Johns Hopkins University, and T. Isshiki, Engineer, Shibaura Engineering Works.

Friday Afternoon, February 20

Room No. 1, 5th Floor, 2:30 p.m.

13. *Oscillographs and Their Tests*, by A. E. Kennelly, Professor of Electrical Engineering, Harvard University, and the Mass. Institute of Technology; R. N. Hunter, Engineering Department, American Telephone and Telegraph Co., and A. A. Prior, Instructor Case School of Applied Science.
14. *The Accuracy of Commercial Measurements*, by H. B. Brooks, Physicist, U. S. Bureau of Standards.

ENTERTAINMENT

Dinner—Dance

A Dinner-Dance will be held at the Hotel Astor, Broadway and 44th Street, New York, Thursday evening, February 19, 1920, at 7:00 o'clock. The purpose of the dinner-dance is to provide a pleasant social function for the entertainment of the members and their guests in attendance at the convention.

The dinner will be served at 7:00 o'clock and prompt attendance is desired in order that the Entertainment Committee's arrangements may be carried out as planned.

The subscription price is $5.50 per person.

The tables will accommodate eight or ten persons each. Members are requested to make up their own tables and to state their seating preference to the committee. Communications should be addressed to the Committee on Entertainment, A. I. E. E., 33 West 39th Street, New York.

Inspection Trips

The following companies have courteously offered to open their plants for inspection by members and guests, either individually or in groups, on dates and at hours indicated. The A. I. E. E. convention badge will be accepted as sufficient identification for direct admission to plants or for the issuance of passes where such are required. Directions for reaching plants can be obtained at registration booth.

Wednesday, February 18th, from 2 p.m. to 5 p.m.

American Telephone and Telegraph Company.—Research Laboratories of the Bell System at Western Electric Company's building, 463 West Street. Conveyances will be provided to the laboratories leaving Engineering Societies Building at 2 p.m. Chemical Transmission, Physical, Circuit, Radio Design, Research, Automatic, and Printing Telegraph Laboratories.

Thursday, February 19th, 9 a.m. to 4 p.m.

New York Edison Company.—Waterside Power Stations, East 38th-40th Streets and First Avenue; Substation, 115-117 West 39th Street.

Wednesday, Thursday and Friday, February 18, 19 and 20th.

9 a.m. to 4 p.m.

Brooklyn Edison Company.—Gold Street Station, foot of Gold Street, Brooklyn.

10 a.m. to 4 p.m.

Brooklyn Rapid Transit Company.—Station at Kent and Divison Avenues, Brooklyn.

9 a.m. to 5 p.m.

United Electric Light and Power Company.—Power Station at 201st Street and Harlem River; West Farms Substation.

9 a.m. to 5 p.m.

Public Service Electric Company.—Essex Power Station, Newark, N. J.

10 a.m. to 4 p.m.

New York Central Railroad.—Port Morris Power Station, 143rd Street and Southern Boulevard, New York.

10 a.m. to 4 p.m.

Interborough Rapid Transit Company.—59th Street Power Station, 600 West 59th St., New York; 74th St. Power Station, 74th St. and East River, New York; Substation No. 42, 57th St. and 3rd Ave., New York.

FUTURE A. I. E. E. MEETINGS

March 12, 1920, Pittsburgh. Meeting under auspices of Traction and Transportation Committee. Subject: Electric Traction. Papers will be presented on "The Design of the Chicago, Milwaukee & St. Paul Locomotives," "Short-Circuit Protection for D-C. Substations," and "Automatic Substations."

April 9, 1920, Boston. Joint Meeting with the American Electrochemical Society. Meeting under auspices of Committee on Electrochemistry and Electrometallurgy.

May 21, 1920, New York. Annual business meeting of the Institute.

June 22 to 25, 1920. Annual Convention.

FUTURE SECTION MEETINGS

Milwaukee.—May 19, 1920. Engineers Society of Milwaukee under auspices of the Electrical Section. Speaker: Professor V. Karapetoff. Subject: "The Coming Science of Acoustical Engineering."

Schenectady.—February 6, 1920. Mr. Calvert Townley, President, A. I. E. E., will address the Section.

February 20, 1920. Paper: "Railway Electrification," to be read by Mr. A. H. Armstrong.

Washington, D. C.—February 10, 1920. Subject: "Electric Propulsion of Ships." Speaker: Mr. A. B. Cheyney, Navy Department.

March 9, 1920. Subject: "Electrolysis." Speaker: Mr. B. McCollum, Bureau of Standards.

March 19, 1920. Joint meeting with Illuminating Engineering Society. Subjects: "Development of the R. L. M. Standards for Industrial Lighting" and "Residence Lighting." Speakers: Messrs. W. Harrison, National Lamp Works, and M. Luckiesh, Nela Research Laboratory.

April 13, 1920. Subject: "Transmission Line Problems." Speaker: Mr. Harold Goodwin, Jr., G. E. Co.

FEBRUARY MEETING OF THE A. I. M. E.

The American Institute of Mining and Metallurgical Engineers will hold a meeting in New York February 16th to 19th, 1920, and extends an invitation to the members of the A. I. E. E. to attend any or all of the sessions. The topics to be discussed are as follows:

Monday	10 a. m.	Oil.
	2 p. m.	Oil.
Tuesday	10 a. m.	Oil.
	2 p. m.	Oil.
Monday	2 p. m.	Coal.
Tuesday	10 a. m.	Geology and Mining.
Tuesday	2 p. m.	Mining and Milling.
Wednesday	10 a. m.	Non-Ferrous Metals.
Wednesday	10 a. m.	Iron and Steel. (Manufacture)
Wednesday	2 p. m.	Alloy Steels. (Physical properties)
Wednesday	2 p. m.	Iron and Steel. (Physical properties)

A large number of papers under these general headings will be presented and discussed. The meeting will conclude with an excursion on Thursday.

INSTITUTE MEETING IN CHICAGO

The 357th meeting of the American Institute of Electrical Engineers was held in Chicago, January 9th and 10th, 1920, under the auspicies of the Chicago Section. Technical sessions were held in the afternoon at the headquarters of the Western Society of Engineers and in the evening at the City Club. The attendance at the afternoon session was about two hundred and at the evening session about three hundred.

The Board of Directors of the Institute held a meeting on Friday morning, January 9th, at the rooms of the Western Society of Engineers, Chicago. Present: Vice-President C. E. Skinner, Pittsburgh; Managers, Charles S. Ruffner, Wm. A. Del Mar, New York, Charles Robbins, Pittsburgh, E. H. Martindale, Cleveland, F. F. Fowle, Chicago; Secretary F. L. Hutchinson, New York.

Reference to the important matters discussed at this meeting may be found in this and future issues of the JOURNAL under suitable headings.

The afternoon technical session was called to order by Mr. A. F. Riggs, Chairman of the Chicago Section, who after a few words of welcome turned the meeting over to Vice-President C. E. Skinner who presided in the absence of President Townley.

Mr. Skinner spoke briefly of the success of the policy of having National Meetings from time to time, away from New York Headquarters, many of which meetings have been more largely attended than some of the regular meetings in New York, and also called attention to the fact that the present meeting was a joint meeting of the Chicago Section of the Illuminating Engineering Society, the Electrical Section of the Western Society of Engineers and the A. I. E. E. He then called upon Mr. Cravath, Chairman of the local committee on arrangements, and Chairman of the Electrical Section of the W. S. E. who opened the meeting.

Mr. Cravath called for the first paper of the meeting entitled "The Series System of Street Lighting Distribution," by W. B. Hurley, and in the absence of Mr. Hurley, the paper was read by Mr. Edgar Switzer. Following the presentation of the paper, the discussion occurred, which was participated in by A. E. Bettis, F. F. Fowle, F. A. Vaughn, W. F. Parker, E. N. Lake, Mr. Cameron, C. H. Shepard, W. A. Del Mar, Mr. Nixon and Mr. Switzer.

The Chairman called for the next paper which was entitled, "Multiple Systems of Distribution for Street Lighting," which was presented by the author, Ward Harrison, and the discussion followed, by N. B. Hinson, I. M. Humiston, Mr. Shepard, Mr. Vaughn, H. Goodwin, Jr., Mr. Peaslee, Mr. Cameron and Mr. Harris.

An informal dinner was held in the City Club at 7.30, following which, a paper was presented by Doctor C. P. Steinmetz, on "Constant Potential, Series Distribution for Street Lighting." A discussion followed by C. E. Clewell, (by letter), J. R. Cravath, Mr. Vaughn, Henry Nixson, Mr. Roper and Mr. Harris. An interesting feature in the discussion was the exhibit of a large number of lantern slides by Mr. F. A. Vaughn, illustrating recent Street Lighting Development in Milwaukee.

On Saturday morning, January 10th, an inspection trip was made by seventy members and guests, to a recently completed Street Lighting Sub-station of the City of Chicago on the Northwest Station of the Commonwealth Edison Company. Transportation was provided by special cars of the Chicago Surface Lines.

ECONOMICAL SUPPLY OF ELECTRIC POWER

FOR THE INDUSTRIES AND RAILROADS OF THE EAST ATLANTIC SEABOARD

The above title forms the general subject of a symposium which has been scheduled for the Midwinter Convention session on Thursday morning, February 19th. The specific subjects to be presented and the contributors to the symposium are as follows:

Large Steam Turbines. Messrs. W. L. R. Emmet and Francis Hodgkinson.

Large A-C. Generators. Messrs. H. G. Reist and F. D. Newbury.

Heavy Traction Locomotives. Messrs. William B. Potter, N. W. Storer and B. G. Lamme.

Transmission and Distribution. Messrs. L. C. Nicholson, Arthur E. Silver and Percy H. Thomas.

The subject of economical power in the region of the Atlantic Seaboard is closely allied to the proposed super-power project discussed by Mr. W. S. Murray in the January JOURNAL. The following extracts from a letter addressed to the above contributors to the symposium, by Mr. Murray, chairman of the Traction and Transportation Committee gives a general idea of the broad engineering features to be considered:

It has been said that the clash of rival systems has delayed the electrification of railroads. This, in my opinion, is true; but I question whether such a result, after all, has not been beneficial

Fifteen years has been the period over which we have had opportunity to analyze the theory and practise of railway electrification.

Had we known fifteen years ago what we know today about electrification, and therefore could have decided the proper system to apply to each case, the financial stress under which the railroads were laboring would have prevented electrification.

Today the industrial demand for power has grown so prodigiously that faced with the old methods of power production which we have been perpetuating, we find ourselves faced with two factors, greatly militating against securing and maintaining supremacy in world's trade. Viz.: (1) throttled production, and (2) waste of the nation's natural resources.

The past fifteen years of education have opened the eyes of the "opposing camps" to certain fundamental factors which will now permit a prompt unanimity of opinion regarding what system applies. The railroad managers have in the past justly taken the ground that since we could not make up our minds which system was correct, they would wait until we could. But, as stated before, I believe that finance and not system has been the real cause of lack of action on the part of the railroads to electrify and that the delay has been truly beneficial since we can now stand on more solid ground for decision.

I am enclosing copy of an address made before the Connecticut Chamber of Commerce, November 19th, 1919.

While the super-power line as described in that address is an important adjunct to the plan proposed, the central idea is the indorsement of central station expansion through means of which national production may be increased and the conservation of our natural resources made secure.

As the major demand for power in the territory between Boston and Washington is for industrial purposes, I believe that I will be supported in the following conclusion:

(a) That prime generating machinery should be three-phase.

(b) That the power to be applied to railroads should be through synchronous motor generators with the synchronous motor fields designed

to relieve to a maximum degree the direct current excitation of the prime generating machinery.

(c) That the question of whether train propulsion be by direct or by alternating current should be settled purely upon the economic relations existing between the generating side of the motor-generator substations and the driving wheels of the motive power. In saying this I realize that this robs the single-phase system of the argument to which it has justly laid claim by virtue of the higher efficiency of static versus rotative substations.

Railroad electrifications, in the past, have been individual to themselves. Today I believe that you will agree that they will form only a part of a whole and indeed be a smaller part, the industrial load being the greater—both receiving power from the same source.

I would like to be first under the above conditions in recognizing two serious limitations to single-phase generation.

(a) Size of generators.

(b) Low power-factor regulation.

The Paper's Committee have assigned the 18th of February during the Midwinter Convention in New York as the date for the presentation of a composite paper bearing upon the subject as presented in the accompanying pamphlet.

It is respectfully requested that you, as expert authorities in the design and application of the apparatus in your respective fields, keeping in mind the central idea of zone application of power, contribute your ideas, and while doing so, eliminate all thought of the past battle of systems.

I further believe that you will agree that the hour has struck for a united front and that such a paper will help the advance of electricity's rightful use in the industrial and railway field.

ENGINEERING FOUNDATION

REPORT OF PROGRESS

A PROGRESS Report of the Engineering Foundation to United Engineering Society, copy of October, 1919, offers to the members of the society an interesting and comprehensive review of the history and accomplishments of the Engineering Foundation, embracing also a survey of the United Engineering Society. In 1914 a sum of money was presented to the Society as a trust fund, the interest of which was to be used in the promotion of engineering research. This resulted in the Engineering Foundation, and the Engineering Foundation Board, for the administration of the income. The opportunities and obligations of this Board are emphasized in the Report; it is "in effect the trustee in these matters for the whole body of American engineers. It is their instrumentality for the stimulation, direction and support of research. It is, furthermore, the liaison agency between engineers on one hand and other technologists and scientists on the other hand, in activities concerned with research in all branches of the mathematical, physical and biological sciences."

Mr. Ambrose Swasey, the founder of the institution, is a man who has long entertained a desire to exalt the work of the engineer and to add to the accumulated facts which serve to guide him in his undertakings. He was born at Exeter, New Hampshire, in 1846. At eighteen he began to learn the machinist's trade; at twenty-three, with Worcester Reed Warner, he went to the Pratt & Whitney Company, Hartford, Connecticut. In 1880 the two removed to Cleveland, Ohio, and established the business in which their names have since been linked—the manufacture of various precision instruments. But Mr. Swasey is not only an engineer and manufacturer, he is also a traveler and philanthropist. He has journeyed widely, twice circling the earth; and has presented many public gifts other than the endowment funds for the Engineering Foundation. He is a member and has held office in a number of engineering societies; has been granted several degrees; and was made a Chevalier of the Legion of Honor by the French Republic. Mr. Swasey first gave the United Engineering Society two hundred thousand dollars as the nucleus of an endowment, the income of which was to be used "for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." Four years later, in 1918, he added one hundred thousand dollars to the fund, making the present total three hundred thousand dollars.

April 15, 1915, the Engineering Foundation Board held its organizing meeting; and in October, 1916, United Engineering Society provided an office for the Foundation in Engineering Societies Building. The Board, charged with the responsibility of administering the funds, safeguards its expenditures in every way. It supports no project, the merits of which have not been demonstrated by competent inquiry. In the development of such inquiry, it has the co-operation of the National Research Council, an organization of American scientists, engineers and educators, established in April, 1916, which has world-wide scientific affiliations. For a considerable time the Foundation contributed its full strength to the support of this Council in its formative period.

Some of the work accomplished by the Engineering Foundation follows: When the nation was at war, it conducted tests in co-operation with the Committee on Submarine Detection, to determine the value of a veil of spray in reducing the visibility of ships at sea, with results which have been formally reported. It conducted a careful inquiry concerning the practicability and advisability of establishing a hydraulic station for testing large water wheels. It formulated a proposal to the several Founder Societies to undertake a study of engineering society organization for the purpose of developing a possible procedure or series of procedures of such evident merit that they would appeal to those who are likely to be most interested.

The Foundation is now conducting investigations on the following: Wear of gears; directive control of wireless communication; weirs for measurement of water; and mental hygiene of industry. It is moreover assisting the Division of Engineering, National Research Council, in a series of preliminary investigations concerning the desirability of researches along several different specific fields of activity; and is co-operating with the University of Illinois in researches on the Fatigue Phenomena of Metals.

Members who are interested may obtain copies of the Report upon application to F. L. Hutchinson, Secretary A. I. E. E.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FOURTH PLENARY MEETING IN LONDON

The fourth plenary meeting of the I. E. C. was held at the Institution of Civil Engineers, London, October 20-22, 1919. Over 50 delegates representing 19 countries were received by the president, Maurice Leblanc at the opening meeting in the afternoon of October 20. The delegates were welcomed by Sir Richard Glazebrook, C.B., president of the British National Committee, Mr. Roger T. Smith, president of the Institution of Electrical Engineers, and Mr. Everest on behalf of the British Electrical and Allied Manufacturers' Association.

The program of sessions was as follows:

Monday, Oct. 20, at 3:00 p.m., official opening and address of welcome.

Tuesday, Oct. 21, at 10 a.m. and at 3.00 p.m., working sessions of the whole Commission to consider future work of advisory committees and draw up resolutions to present at the plenary meeting.

Wednesday, Oct. 22, at 11:00 a.m., plenary meeting to ratify resolutions.

Wednesday, Oct. 22, at 3.00 p.m., Council meeting.

A Banquet was given by the British National Committee, Council of the Institution of Electrical Engineers, and the Council of the British Electrical and Allied Manufacturers'

Association to the foreign Delegates, on Tuesday evening, at which an address was delivered by the Rt. Hon. A. J. Balfour, O.M.

The working sessions, over which Sir Richard Glazebrook, C.B., was elected to preside, discussed a number of subjects on which definite proposals were formulated for submission to the plenary meeting.

At the plenary meeting advisory committees were appointed or reappointed as follows:

Nomenclature. The Committee was re-appointed and will confine its attention to deleting those terms and definitions which are unacceptable and has power to instruct the Central Office to issue the remaining terms and definitions without reference to a plenary meeting.

Rating of Electrical Machinery. The Committee was re-appointed.

The Plenary Meeting ratified the rules agreed to at the last meeting, together with the modifications and additions proposed at the meetings of the advisory committee held in Paris in May, 1919, and in London in October, 1919.

The Editing Committee and the General Secretary are authorized to edit these decisions which will be published without delay.

Symbols. The Committee was re-appointed to consider Publication 27 issued in 1914. The Committee has power to instruct the Central Office to issue the Publication with desired modifications, without further reference to a plenary meeting.

Prime Movers for Electrical Plant. The Committee was re-appointed to continue the important work which it has so far been engaged upon.

Aluminum. A Committee was appointed to study the question of the adoption of an International standard of resistance for aluminum.

The line adopted for the preparation of the standard of resistance for Copper Publication 28 is to be closely followed. The Directors of the National Physical Laboratories including Prof. Paul Janet of Paris will be invited to collaborate.

Screw Lamp Caps and Lamp Holders. A Committee was appointed to study this question which will confine its report to matters of international interchangeability, questions of material not being dealt with.

Charging Plugs for Electrical Vehicles. A Committee was appointed to study the question of international interchangeability only. It is understood that the charging plugs used in the United States and Great Britain are identical.

Standard Pressures for Distribution and Insulators. A Committee was appointed to study the question of standard pressures for insulators and subsequently make a comparative study of high tension distribution pressures. The Committee will work in close conjunction with the Committee on Rating.

It was decided to hold Meetings of the Advisory Committees in Brussels in the early Spring of 1920, the Central Office being empowered to make the necessary arrangements for these Meetings.

At the Council Meeting held on Wednesday, October 22nd., Dr. Mailloux, President of the U. S. National Committee, was unanimously elected as the new President of the I. E. C. Dr. Mailloux was one of the founders of the Commission, and its success has been due in no small measure to his efforts on its behalf. His great linguistic abilities have been of the utmost service on many occasions.

In view of the general rise in prices it was agreed that each Committee should be asked to double its subscriptions.

The Council accepted the invitation of the U. S. National Committee to hold the next Plenary Meeting in the United States of America during the summer of 1920.

At the close of the Meeting Dr. Mailloux, on behalf of all his friends, presented a silver cup to Col. R. E. Crompton, the Honorary Secretary of the Commission.

ANALYSIS OF WORK ACCOMPLISHED

So far as relates to the subject of Rating of Electrical Machinery, the work accomplished falls into two categories. In the first category is the work which was ratified on October 22nd, the last day of the plenary meeting. In the second category is further work done by the Advisory Committee on Rating of Electrical Machinery which continued in session for three more days. The work in this second category will be brought together as a recommendation of the Advisory Committee, and will not, until ratified at a plenary meeting, have the status of I. E. C. Rules. Even the portion ratified at the plenary meeting was in the form of notes from which the Editing Committee of the I. E. C. was authorized to prepare the official report. This report will be the one submitted to the various National Committees for study.

Consequently, at the present time, any statement of the things done must be made with reservations. It does not seem worth while to attempt to distinguish between the different degrees of completeness of the work done. The best that can be done is to state the general trend of matters.

I. For the purposes of the I. E. C. Standards, electrical machinery is, for the present divided into two groups.

In the first group fall:

1. Rotating machines of which the terminal pressures do not exceed 5000 volts, or of which the rated output does not exceed 750 kv-a., or of which the stator cores do not exceed 50 cm. in length, measured axially.
2. All transformers which are not water-cooled.

II. For machines in this group, there are recognized only two methods of temperature measurement for acceptance tests, namely:

1. Resistance and thermometer, which ever gives the highest.
2. Thermometer measurements.

III. For machines whose terminal pressures exceed 5000 volts or of which the rated output exceeds 750 kv-a., or of which the stator cores have an axial length greater than 50 cm., a third method of temperature measurement, namely by embedded temperature detectors was recognized, by the Advisory Committee on Rating. This has, at present, no more status than that of being the recommendation of that Committee.

IV. The alternative of permitting thermometer measurements alone with a five-degree penalty, practically as customary in America, has been adopted by the Committee on Rating although with certain modifications.

V. Commutators and slip-rings are permitted to have any temperature consistent with successful operation, but if temperature rises of more than 50 degrees are employed for commutators the manufacturer shall give a special guarantee that the temperature obtained shall not impair the commutation.

VI. An Ambient Temperature of Reference of 40 deg. cent. for air was adopted for I. E. C. ratings.

VII. The I. E. C. Committee on Rating purposes to consider the adoption of an ambient temperature of reference for tropical ratings. Amongst the values mentioned informally, considerable stress was laid upon the appropriateness of 55 degrees. If this should ultimately be adopted, it would amount to a 15 degree lower temperature rise for machines with a tropical rating.

VIII. An Ambient temperature of reference of 25 deg. cent. for water was recommended for I. E. C. ratings by the Advisory Committee on Rating.

IX. For water-cooled transformers the Advisory Committee on Rating recommended that the limits for the highest observable temperatures shall be decreased by 10 deg. below those permitted for other machinery. Since the ambient temperature of reference for water is 15 deg. below that for air, this amounts to permitting a 5-degree greater temperature rise for water-cooled transformers than for transformers of other types.

X. The Advisory Committee on Rating recommends a

temperature-limit of 90 deg. cent. for the oil in which transformers are immersed.

XI. The principle of correction back to shut-down is recognized.

XII. The permitted temperature limits for non-impregnated cotton, silk and paper are 15 degrees below the limits for these materials when impregnated.

XIII. The rule for the duration of the temperature test for a machine with a continuous rating is that the test shall be continued until it is evident that the maximum temperature rise attained would not exceed the prescribed limits if the test were to be prolonged until the final steady temperature were attained.

XIV. Very satisfactory progress was made by the Advisory Committee on Rating in its recommendations concerning High Voltage Tests. So far as the matter was carried, the Rules recommended are in quite good agreement with those already adopted in several countries, including America.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

CLASSIFICATION OF ENGINEERS

A COMPLETE and definite classification for engineers in Federal, State, County, Municipal and Railroad service was approved by Engineering Council at its meeting on December 18th, 1919, when it adopted the classification proposed in the third progress report of its Committee on Classification and Compensation of Engineers, of which Arthur S. Tuttle, Member, Am. Soc. C. E., is chairman. Eight grades are defined, five professional and three sub-professional, and the necessary qualifications are specified. A striking comparison of the results of this latest investigation into Federal, State and Municipal service with those reported in 1917 by the committee of the American Society of Civil Engineers appointed to investigate the conditions of employment and compensation of civil engineers was pointed out in the committee report.

The extracts of this report which follow include, in addition to the classification and the above-mentioned comparison, an interesting tabulation of average salaries in Federal, State and Municipal service, with average ages of the incumbents and average salaries recommended by the engineers in charge. The Committee asked for an appropriation of $10,000 for the purpose of continuing the investigation into present salaries and to insure publicity and progress in the effort to raise the level of engineering compensation. This is one of the items for which Engineering Council is making its appeal for funds.

Findings and Conclusions of the Committee

The investigations have shown the lack of any adequate or consistent employment policy with respect to professional engineers. This is evidenced by the following conditions which are believed to be largely responsible for the unsatisfactory status of men engaged in this class of work:

1. Absence of any uniform system of grading of positions.
2. Lack of uniformity in titles of positions with respect to duties.
3. Inequalities in compensation for positions of the same grade.
4. Generally inadequate compensation for services rendered.

To the end that these conditions may be corrected and proper and equitable conditions of employment established, the following principles and practises are recommended by the Committee, though not yet acted upon by Council.

1. Positions should be classified in accordance with the type of work, and with the character of the duties to be performed and the qualifications necessary for their performance, as indicated by a system of grading.
2. Within the salary limits fixed for each grade, there should be a system of advancement through the grade based upon experience gained in the position and upon proof of increase in the proficiency of the employee in performing the duties of the grade.
3. Promotions from grade to grade should depend upon the existence of a vacancy in the higher grade and proof that the employee is qualified to fill the vacancy.
4. The determination of salary adequate to procure for and retain in engineering work a high class of employees, should take into account and properly weigh the following considerations:
   (a) The capital invested, both in money and in time, in obtaining the requisite fundamental training.
   (b) The amount and character of experience and the degree of personal ability required.
   (c) The relative value of the classes of work to be performed.
   (d) The amount paid for similar service in other lines of work.
   (e) The amount necessary to enable the employee to maintain a standard of living commensurate with the general standards of the community for positions of similar dignity and responsibility.
5. In the interest of an adequate social policy, no position likely to be occupied by individuals of an age to assume family responsibilities should fail to pay an amount sufficient to permit the maintenance of the average family in reasonable decency and comfort.
6. In the interest of the employees as a whole and of the employer, a system should be established by which employees who fail to maintain satisfactory standards of service should be removed, transferred, demoted, or retired as may be equitable in the circumstances.

Classification of Engineering Positions in Federal, State, County, Municipal and Railroad Services

The grades proposed, which appear to be well adapted to use not only in all of the services represented but also for all other forms of engineering activities, have been divided into two classes, the Professional Service being deemed to include men who have received an engineering degree from an educational institution of recognized standing or who have obtained similar qualifications through practise of the profession and by mastering the fundamentals of engineering science, while the Sub-Professional Service includes assistants with at least a high school education, who enter upon the practise of the profession in the performance of responsible duties for which an

engineering training is not essential, but who through experience and study may fit themselves for the higher grades. The classification is as follows:

PROFESSIONAL SERVICE

Grade 1.—Chief Engineer

Duties. To act in chief administrative charge of a technical organization, or of a main division thereof; to determine the general policies of the organization under the limitations imposed by law, regulation, or other fixed requirement; to have final responsibility for the preparation of reports, cost estimates, designs, and specifications and for the construction, maintenance, or operation of engineering works or projects; to have full charge of the collection and presentation of data for and the conduct of valuation proceedings; to conduct or direct the most comprehensive lines of engineering research.

Qualifications. Training and experience of a character to give substantial evidence of engineering knowledge and ability or of executive capacity of highest order along lines of work similar to those involved in the position to be occupied and of at least twelve years' duration, of which at least four years shall have been spent in duties of Engineer or their equivalent and at least five years in responsible charge of important work or projects. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 2.—Engineer

Duties. Under general administrative direction and within the limits of the general policies of the organization, to have responsible charge of and to initiate and determine policies for a major subdivision of an organization; to prepare for final executive action reports, cost estimates, designs, specifications, and valuation studies and data; to have immediate charge of the construction, maintenance, or operation of engineering works or projects of major importance; to conduct or direct major lines of engineering research; or to furnish for executive action expert or critical advice on engineering works, projects or policies.

Qualifications. Active professional practise or executive charge of work for at least eight years, of a character to demonstrate a high degree of initiative and of ability in the administration, design, or construction of engineering work or projects of major importance, of which at least three years shall have been spent in duties of Senior Assistant Engineer, or their equivalent, and at least three years in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 3.—Senior Assistant Engineer

Duties. Under general administrative and technical direction, to be in responsible charge of an intermediate division of an organization; to exercise independent engineering judgment and assume responsibility in studies and computations necessary for the preparation of reports, cost estimates, designs, specifications, or valuations; to have immediate charge of the construction, maintenance, or operation of important engineering works or projects; or to conduct or direct important lines of engineering research.

Qualifications. Active professional practise or executive charge of work for at least five years, of which at least three years shall have been spent in duties of Assistant Engineer, or their equivalent, with at least one year in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 4.—Assistant Engineer

Duties. Under specific administrative and technical direction, to be responsible for the conduct of the work of a minor subdivision of an organization; to collect and compile data for specific items of engineering studies; to take immediate charge of field survey projects and of the design and construction of minor engineering work; to lay out and develop work from specifications and to supervise the work of a drafting or computing force; or to conduct specific tests or investigations of apparatus, material, or processes.

Qualifications. Experience for at least two years in duties of Junior Assistant Engineer or their equivalent. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing, or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

Grade 5.—Junior Assistant Engineer

Duties. Under immediate supervision, to perform work involving the use of surveying, measuring, and drafting instruments; to take charge of parties on survey or construction work; to design details from sketches or specifications; to compute and compile data for reports or records; to inspect or investigate minor details of engineering work; or to perform routine rests of apparatus, material, or processes.

Qualifications. No experience required other than that involved in securing a professional degree upon the completion of a standard course of engineering instruction in an educational institution of recognized standing; but in absence of such degree, a high school education or its equivalent is required and at least four years' experience in the use of surveying, measuring or drafting instruments, or the computation and compilation of engineering data, together with evidence of a knowledge of the fundamentals of engineering science sufficient, with further experience, to qualify for the higher professional grades. The completion of each full year of such standard course of engineering instruction shall be considered as the equivalent of one year of experience.

SUB-PROFESSIONAL SERVICE

Grade 6.—Senior Aid, Office

Duties. To supervise the plotting of notes and maps, and to direct the work of a drafting or computing squad.

Qualifications. Experience for at least five years in tracing, lettering, drafting, and computing, of which at least three years shall have been spent in the duties of draftsman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of draftsman.

Grade 6.—Senior Aid, Field

Duties. To direct work of field party on surveys or construction; to keep survey notes and engineering records; to

supervise construction or repair work; to direct the work of computing surveys and estimates; to direct the work of making minor engineering computations.

Qualifications. Experience for at least five years in the use and care of surveying instruments, of which at least three years shall have been spent in the duties of instrumentman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of instrumentman.

Grade 7.—Aid, Office

Duties. To prepare general working drawings where design is furnished; to plot notes and prepare maps; to design simple structures; to make computations and compile data for reports and records; to check plans, surveys, and other engineering data.

Qualifications. Experience for at least two years in tracing, lettering, drafting, and computing. Education equivalent to graduation from high school and familiarity with the use of the slide rule, and of logarithmic and other simple mathematical tables. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

Grade 7.—Aid, Field

Duties. To run surveying instruments and to adjust and care for same; to compute surveys and estimates; to make minor engineering computations; to inspect incidentally construction or repair work.

Qualifications. Experience for at least two years in the duties of rodman. Education equivalent to graduation from high school and familiarity with the construction, operation, and care of surveying instruments. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

Grade 8.—Junior Aid, Office

Duties. To trace and letter maps and plans; to make simple drawings from sketches and data; to make minor calculations.

Qualifications. Education equivalent to graduation from high school.

Grade 8.—Junior Aid, Office

Duties. To run tape or levelling rod; to perform other miscellaneous subordinate duties in survey party in field or office, as directed.

Qualifications. Education equivalent to graduation from high school.

Experience Equivalents for Post-Graduate Work

The completion of each full year of post-graduate work in the specific subject of study or investigation appropriate to a particular service or branch of service shall be considered the equivalent of one and one-half years of general experience, but such substitution shall not thus be made for more than four years of such experience or be considered as reducing the requirements in any grade of the number of years engaged in the conduct or direction of responsible work.

An examination of the schedule shows that the minimum experience requirements for the various grades may be briefly summarized as follows:

Service	Grade	Experience in Years With Degree in Engineering	Experience in Years Without Degree in Engineering
Sub-professional	8—Junior Aid	0	0
	7—Aid	0	2
	6—Senior Aid	0	5
Professional	5—Junior Assistant Engineer	0	4
	4—Assistant Engineer	2	6
	3—Senior Assistant Engineer	5	9
	2—Engineer	8	12
	1—Chief Engineer	12	16

The following table illustrates the practicability of adapting the proposed classification to any particular grade or branch of the engineering service and in such a way as to clearly retain a description of the relative rank.

PROFESSIONAL SERVICE

1.—Chief Engineer

Chief Engineer	Deputy Chief Engineer
State Engineer	Deputy State Engineer
City Engineer	Deputy City Engineer
Chief Engineer of Maintenance of Way	Director, etc.

2—Engineer

Electrical Engineer	Division Engineer
Mechanical Engineer	District Engineer
Mining Engineer	Sewer Engineer
Chemical Engineer	Topographical Engineer
Bridge Engineer	Landscape Engineer
Sanitary Engineer	Hydraulic Engineer
Tunnel Engineer	Geodetic Engineer
Maintenance of Way	Engineer Structural Engineer
Signal Engineer	Valuation Engineer
Highway Engineer	Designing Engineer, etc.

3—Senior Assistant Engineer

Senior Assistant Electrical Engineer
Senior Assistant Mechanical Engineer
Senior Assistant Mining Engineer
Senior Assistant Chemical Engineer
Senior Assistant Bridge Engineer, etc.

4—Assistant Engineer

Similar to Senior Assistant Engineer

5—Junior Assistant Engineer

Engineer Inspector, etc.

SUB-PROFESSIONAL SERVICE

6—Senior Aid

Office: Chief Draftsman	Field: Chief Instrumentman
Chief Computer	Chief Inspector

7—Aid

Office: Draftsman	Field: Instrumentman
Computer	Inspector

8—Junior Aid

Office: Junior Draftsman	Field: Rodman
Tracer	Tapeman

Striking Comparison of Results of Investigations Into Compensation

In 1913 a committee was appointed by the Board of Direction of the American Society of Civil Engineers to investigate the conditions of employment and compensation of civil engineers. This committee was headed by the late Alfred Noble, who was succeeded as chairman by Nelson P. Lewis. In its final report, presented at the annual meeting of the Society held in 1917, the committee gave the results of its canvasses, com-

prising returns from 6378 engineers, of whom 1319 were non-members. The distribution among the various services of such returns as could be classified showed an average compensation as follows:

Service	Number of Classified Men	Average Compensation
States and Counties	387	$2,735
National Governments	575	2,899
Municipalities	764	2,994
Technical Schools	262	3,240
Railroads	814	3,325
Private Companies	2,198	4,240
Consulting Engineers	620	6,737
Contractors	165	7,678
	5,785	$4,032

The committee advised that the analysis of the returns showed that the pay received by members of the Society was generally about 25 per cent above that of non-members. It also stated that an effort had been made to obtain information from Railroad, Municipal, State, and Federal Departments but that the officials in authority considered it impracticable to undertake a collection of the desired data, and in the absence of this co-operation no headway could be made. The committee also reported that from the meager information obtained it was "convinced that the compensation for engineering work compares favorably with that received by men of any other profession," and that there was need for "better trained engineers rather than of more engineers."

That a radical change of heart has since taken place on the part of responsible department heads is clearly evidenced by the fact that practically the entire Federal engineering service, except the War Department, has co-operated in the present inquiry, as have also 42 per cent of the state officials, and 70 per cent of the municipal officials, and that the financial status of 10,089 men in these grades has now been revealed as compared with a total of 1726 men, in the same classes of service, who replied to the 1913-1916 inquiry. It also appears that the respondents in the case of the previous investigation were largely confined to the classes receiving maximum compensation, the average rate of present compensation shown by the new return being as follows:

Service	Number of Men	Average Compensation
Federal Government—Navy Department	594	$2,474
Federal Government—(excluding War and Navy Departments)	3,956	1,814
Federal Government—(excluding War Department)	4,550	1,900
State	2,222	1,700
Municipal	3,317	1,820

In comparing these returns with those received by the previous committee, the decrease in the value of the dollar should also be borne in mind.

Results from Questionnaires

Tables 1, 2 and 3 include partial results of the analysis of Federal, State and Municipal returns from questionnaires received up to the date of the committee report, December 15th, 1919.

TABLE I.—FEDERAL SERVICE, SUMMARY OF PRESENT SALARIES BY GRADES.

General description of duties.	16 engineering bureaus in civil establishments.					4 engineering bureaus in Navy department.				
	No. of persons.	Present pay per annum. Average.	Present pay per annum. Maximum.	Present pay per annum. Minimum.	Per cent increase of the average since July 1, 1915.	No. of persons.	Present pay per annum. Average.	Present pay per annum. Maximum.	Present pay per annum. Minimum.	Per cent increase of the average since July 1, 1915.
Chief administrative officer having full charge of organization including determination of policy	15	$5,867	$10,000	$4,500	3.0	2	$9,450	$9,900*	$9,000*	0.0
Chief of major subdivision in responsible charge of large unit	83	3,801	7,500	1,800	5.0	4	6,381	9,000*	5,200	0.0
Chief of intermediate subdivision in responsible charge.	209	3,104	5,000	1,800	9.9	22	4,312	5,634	2,304	57.6
Chief of minor subdivision	846	2,222	4,500	1,020	9.0	54	3,600	4,883	2,304	58.2
On general duty under direction but requiring special education and training and the use of initiative and originality	1,353	1,719	3,000	1,000	13.3	192	2,818	3,756	1,878	52.2
On subordinate duty requiring special education or training but not requiring special originality	1,092	1,293	2,817	600	12.0	218	1,954	4,257	1,500	38.4
On subordinate duty but not requiring special education, training, or originality	169	975	1,340	480	19.3	81	1,379	2,254	1,002	37.2
On special duty of responsible character requiring special qualifications and initiative	189	1,812	7,500	1,200	3.9	21	2,717	4,382	1,628	1.3
Total	3,956					594				

*Naval Officers, all others are civilian.

TABLE II.—STATE SERVICE. ANALYSIS OF RETURNS SHOWN BY 35 QUESTIONNAIRES FROM 27 STATES

Position.	Number of persons now in position.	Age, years.*		Average Compensation per annum.*			Per cent increase in compensation over July 1st, 1915.*	
		Range.	Average.	July 1st, 1915.	July 1st, 1919.	Recommended.†	Actual on July 1st, 1919.	Recommended.†
Professional								
Chief Engineer	31	30–70	41	3,743	4,481	7,124	20	90
Deputy Chief Engineer	19	30–51	38	3,352	3,616	4,477	8	34
Engineer	80	30–50	37	2,530	3,019	3,934	19	56
Senior Assistant Engineer	111	30–50	32	1,981	2,429	3,222	23	63
Assistant Engineer	396	27–42	33	1,657	2,140	2,758	29	66
Junior Assistant Engineer	529	21–36	27	1,130	1,595	2,100	41	86
Staff	1,166	21–70		1,590	2,070	2,730	30	72
Sub-Professional.								
Senior Draftsman	29	25–40	31	1,508	1,868	2,327	24	54
Draftsman	141	22–50	28	1,224	1,653	1,944	35	59
Junior Draftsman	110	20–25	22	924	1,227	1,394	33	51
Chief Instrumentman	61	24–40	27	1,297	1,611	1,915	24	48
Instrumentman	193	22–30	23	1,243	1,498	1,773	21	43
Rodman	522	18–26	20	791	1,057	1,148	34	45
Staff	1,056	18–50		995	1,290	1,470	30	48
Entire service	2,222	18–70		1,310	1,700	2,130	30	63

*Based on such returns as are complete.
†As recommended by the engineering heads replying to questionnaire.

TABLE III.—MUNICIPAL SERVICE. ANALYSIS OF RETURNS SHOWN BY 66 QUESTIONNAIRES FROM 40 CITIES

Position.	Number of persons now in position.	Age, years.*		Average Compensation per annum.*			Per cent increase in compensation over July 1st, 1915.*	
		Range.	Average.	July 1st, 1915.	July 1st, 1919.	Recommended.†	Actual on July 1st, 1919.	Recommended.†
Professional.								
Consulting Engineer	8	39–70	55	5,457	6,410	8,550	18	57
Chief Engineer	64	30–64	44	5,424	5,467	7,465	1	38
Deputy Chief Engineer	19	35–60	48	4,624	4,901	6,320	6	37
Engineer	165	30–68	46	3,446	3,679	4,749	7	38
Senior Assistant Engineer	265	30–64	41	2,428	2,616	3,293	8	36
Assistant Engineer	505	27–53	40	1,902	1,999	2,613	5	37
Junior Assistant Engineer	452	25–45	34	1,415	1,548	1,812	9	28
Staff	1,478	25–70		2,230	2,370	3,020	6.5	36
Sub-Professional.								
Senior Draftsman	100	28–53	42	1,777	1,982	2,356	12	33
Draftsman	442	25–65	35	1,395	1,626	2,008	17	44
Junior Draftsman	118	21–48	26	1,055	1,205	1,439	14	36
Chief Instrumentman	88	28–53	40	1,454	1,700	2,162	17	49
Instrumentman	448	22–52	38	1,174	1,426	1,737	21	48
Rodman	643	17–52	32	868	1,056	1,352	22	56
Staff	1,839	17–65		1,160	1,370	1,700	18.5	47
Entire Service	3,317	17–70		1,640	1,820	2,290	11	40

*Based on such returns as are complete.
†As recommended by the Engineering heads replying to questionnaire.

It is thus disclosed that the average compensation for grades representing 68 per cent of the engineers in the Federal Service, other than the War Department, and 86 per cent of those in State and Municipal Service, is less than is required for the support of a family on a scale sufficient to provide for necessities (assumed at $2200 per annum), to say nothing of the expense of giving children anything like the education with which the breadwinner was equipped.

It would seem reasonable to assume that men in the "Junior Aid" grade have not reached an age which would require compensation sufficient to support a family, but that the salary limitation for men in higher grades should clearly be sufficient to meet this need. On this basis it is safe to state that with anything like suitable compensation, not more than about 25 per cent of the entire service, if properly organized, should receive less than $2200 per annum. The investigation made

by the State and Municipal Section shows that the average age of the present incumbents of the lowest grades is actually about 27 years; if they are to be adequately provided for as permanent employees, the percentage of men to receive less than $2200 is clearly negligible.

A comparison with the pay of the industrial worker who serves under the engineer also bears testimony to the fact that, while admitted by none as to value, the actual compensation for brawn is to-day greater than for engineering brain. The need for setting up some scale of compensation for the engineer to correct this serious condition is, therefore, obvious, as is also that for the inquiry now being carried on by the Committee. Unless a radical improvement can be brought about, it seems evident that the profession cannot attract to or retain in it men of the caliber required to command the respect in which it has heretofore been held by the public, and that so long as they are continuously struggling with the problem of making even a bare living, their efficiency will be minimized and their incentive to work with other than a purely selfish interest will be lacking.

That a serious condition of unrest exists in the Municipal and State services is clearly evidenced by explicit statements in this respect in 44 per cent of the questionnaires returned, while in only 13 of these services were conditions as to morale reported to be satisfactory.

From the investigation made by each of the sections of the Committee, it appears that the heads of sixteen engineering bureaus in the Federal Government (excluding the Navy Department) have recommended an average increase in present compensation averaging about 59 per cent while similar increases in the State and Municipal Services, as recommended by the engineering heads, average 26 per cent.

As a result of the inquiry now in progress under the direction of the Congressional Joint Commission on Reclassification of Salaries, the attention of all members of the Federal Service has been drawn to this question in such a way as to make it

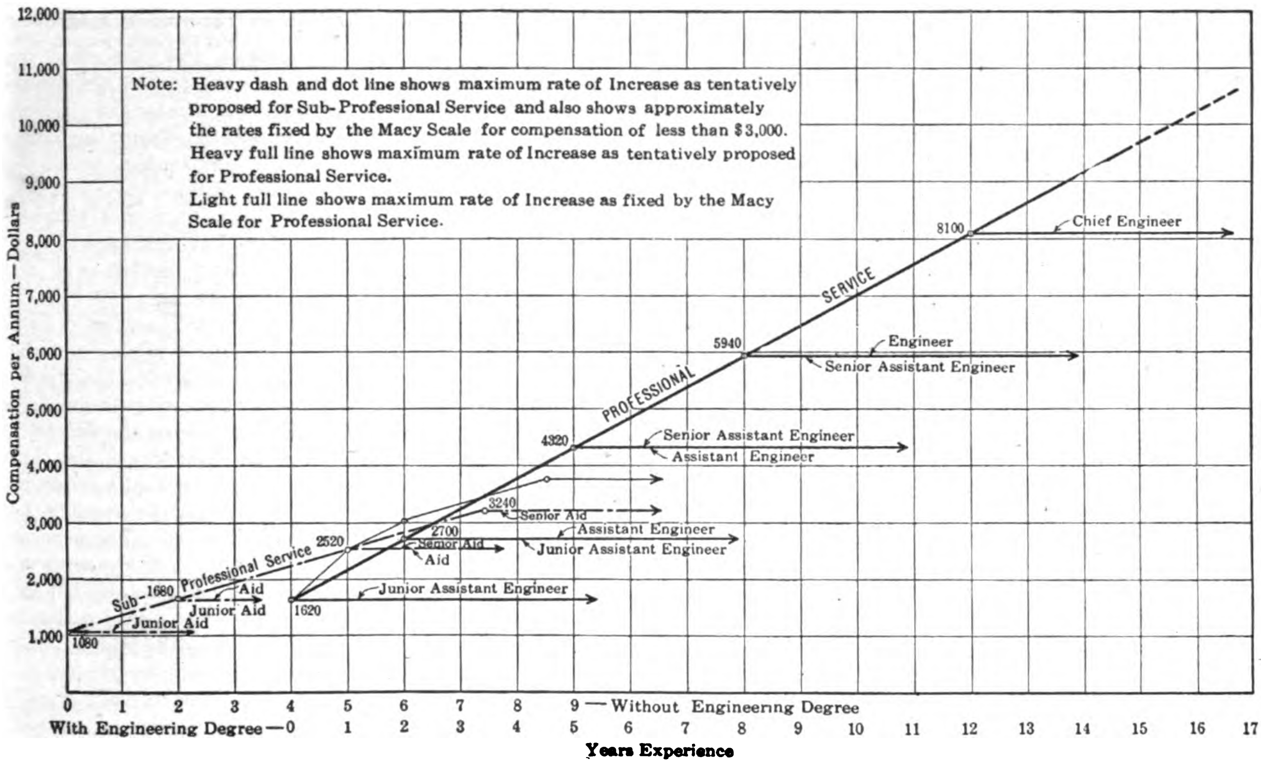

Diagram Showing Maximum Rate of Progress Through the Various Grades as Adopted, and Also Indicating the Compensation Tentatively Proposed for Each Grade

one of close study and analysis, which condition doubtless accounts for the comparatively modest recommendation made by the representatives of the State and Municipal Services, whose reply to our inquiry has been individual and who have doubtless been confronted with the necessity of recognizing relationship to other workers in the same services in whose interests no concerted move of this character has been attempted.

Your Committee is impressed with the method which has been followed by the Federal Section in setting up a standard of compensation based on a readjustment to the new conditions as to cost of living, this being dependent on an award made on October 24, 1918, by the Shipping Wage Adjustment Board, which was designed to provide uniform national wage scale for all shipbuilding workers, including a scale of compensation for draftsmen and copyists. It is also understood that this wage scale, which is generally known as the Macy scale, has since been adapted with modifications to the needs of certain bureaus in the Navy Department. In the accompanying diagram there is illustrated a comparison of the compensation fixed under the Macy Scale with the maximum rates suggested by the Federal Section. A further comparison has also been made with scales proposed by other organizations, which seem to justify the schedule of salaries now suggested by the Committee for discussion, which is as follows:

Grade	Total Years Experience Required to Qualify: With Professional Degree	Without Professional Degree	Salary Range: Minimum	Maximum
8—Junior Aid		0	$1,080	$1,560
7—Aid		2	1,680	2,400
6—Senior Aid		5	2,520	3,240
5—Junior Assistant Engineer	0	4	1,620	2,580
4—Assistant Engineer	2	6	2,700	4,140
3—Senior Assistant Engineer	5	9	4,320	5,760
2—Engineer	8	12	5,940	No limit
1—Chief Engineer	12	16	8,100	No limit

Applying the average proposed salary to the present incumbents of these positions as reported in the State and Municipal Services, it will be found that there would be a resulting increase in annual compensation totalling about $5,500,000 as compared with a total increase of $2,500,000 recommended by the service heads, against which should, however, be charged the economy growing out of the increased efficiency brought about by a restoration of morale.

The Committee is not prepared at this time to recommend the adoption of any definite schedule of compensation, and it is not at all clear as to the wisdom of fixing even a minimum limit on the highest grades of service or of keeping the maximum of one grade below the minimum of the grade above, all of which questions are now receiving its serious consideration, as is also the question concerning the provision to be made for advancing within the limits of a grade, for which a plan is suggested by the Federal Section. Under this plan it is proposed at yearly intervals, through ratings determined by a Personnel Board, to provide for awarding an increase in compensation to three-fourths of the men in a grade receiving less than the maximum compensation of the grade, who through fitness and industry have shown themselves to be of increased value to the service. Those in the highest third of this preferred list would each receive the maximum rate of increase, which under the proposed scale would be $480, while each of the next two-thirds would receive an increase of $240, the latter figure corresponding with what would then be the average increase for all of the men in the grade.

It would seem to the Committee that, pending the completion of the investigation, the scale of compensation herein presented and the plan for promotion within a grade is adapted to general use in all branches of engineering service. The Committee believes, however, that a general discussion of this question is desirable.

The chairmen of the sections of the Committee are as follows:

Classification and Compensation of Engineers

Arthur S. Tuttle, Chairman, Deputy Chief Engineer, Board of Estimate and Apportionment, Municipal Building, New York.

Francis Lee Stuart, Consulting Engineer, 50 East 42nd Street, New York City.

John C. Hoyt, Chief, Division of Water Resources, U. S. Geological Survey, Washington, D. C.

Charles Whiting Baker, Consulting Editor, Engineering News Record, 31 Nassau Street, New York City.

M. O. Leighton, Chairman, National Service Committee of Engineering Council, 502 McLachlen Building, Washington, D. C.

Railroad Section

Francis Lee Stuart, Chairman.

Frank H. Clark, Consulting Engineer, 15 Park Row, New York City.

Bion J. Arnold, Consulting Engineer, 105 So. LaSalle Street, Chicago, Illinois.

State and Municipal Section

Arthur S. Tuttle, Chairman.

M. M. O'Shaughnessy, City Engineer, San Francisco, Cal.

F. W. Cappelen, City Engineer, Minneapolis, Minn.

Federal Section

John C. Hoyt, Chairman

John S. Conway, Asst. Commissioner of Lighthouses, Washington, D. C.

Oscar C. Merrill, Chief Engineer, Forest Service, Washington, D. C.

REGISTRATION OF ENGINEERS

Because of widespread and persistent interest in the subject of licensing or registering engineers, architects and surveyors, Engineering Council, at its meeting of October 25, 1910, authorized the creation of a committee to make a thorough study and submit a report. Fifteen engineers from all parts of our country, and of long experience in the various branches of the profession of engineering were appointed as members of this committee. The committee presented a report to Engineering Council at its meeting December 18, 1919. This report is accompanied by a "Recommended Uniform Registration Law, to regulate the practise of professional engineering, architecture and land surveying." Council voted to receive this report and to give it together with the proposed law, as wide publicity as could be secured in order that discussion might be elicited to guide Council in the consideration of this important matter at its meeting in February 1920. Engineering Council has as yet taken no action upon the merits of the question of the advisability of legislation providing for the registering or licensing of practitioners of the professions named.

Report by Committee on Licensing Engineers

During the past fourteen months, this committee has had under consideration and study the subject of the licensing or registration of engineers. The fifteen members of the committee as appointed by Council, were selected from thirteen states, viz., Connecticut, New York, Pennsylvania, Ohio, Georgia, Louisiana, Illinois, Missouri, Iowa, Minnesota, Colorado, California and Washington, and therefore represent practically all sections of the United States, as well as, mechanical, electrical, mining, hydraulic, municipal, sanitary, railway and structural engineering, and also colleges of engineering.

The first work of the committee was to investigate the general subject and to collect, so far as possible, available material bearing upon the subject in hand, including opinions from many engineers as to the need or desirability of legislation, as well as copies of all state laws passed and proposed, having to do with licensing or registration of engineers, architects and surveyors.

This preliminary investigation disclosed that very pronounced views were held by engineers throughout the country, both for and against state licensing or registration. The general sentiment one year ago was more opposed to such measures than it is today. The older members of the profession did not as a rule favor licensing nor did they feel there was need for state regulation of engineering practise, while among the younger men there was a feeling that licensing or registration by the states would add prestige to professional engineers and in many ways benefit the profession, as well as individual engineers.

The advantages claimed for state licensing or registration are the same as those presumably gained by the laws regulating the professions of law and medicine, namely, that those who are incompetent and unqualified professionally to practise are unable to obtain certificates or licenses and hence both the public and the profession are protected. On the other hand, those engineers who have already attained to recognized professional standing feel they not only do not need the benefits claimed for such legislation, but they fear that state licenses or certificates of registration are apt to put the seal of state endorsement on men who do not deserve it and that the public would assume that a licensed or registered engineer was thereby certified by the state as fully qualified, regardless of what might or might not be the requirements demanded before a license or certificate was granted.

However, the question has gone beyond the stage of debate, for already ten states* have enacted laws licensing or registering engineers, and other states are certain to enact similar laws during the present or coming sessions of their legislatures. In addition to these ten laws governing engineering practise, there are at least six states that require the licensing or registration of

*Colorado, Florida, Idaho, Illinois, Iowa, Louisiana, Michigan Nevada, Oregon, Wyoming.

land surveyors and in at least eighteen states†, laws have been passed licensing or registering architects. Some of these ten laws are so drawn as to include both engineers and surveyors and some include engineers and architects and one or two include engineers, architects and surveyors. Moreover, these laws are not at all uniform and in several instances are likely to prove seriously embarrassing and annoying to engineers whose activities extend beyond the limits of a single state. Because of the nature of professional engineering work the practise of an engineer frequently extends over several states and therefore it is vitally important, if there are to be state regulations for engineering practise that these regulations be made uniform so far as possible and that the engineering profession unites in wisely directing such legislation.

As stated, laws have been passed in seventeen states for licensing or registering architects and the American Institute of Architects has endorsed and advocated such legislation, considering that both the architects and the general public are benefited thereby. Unfortunately some of the laws for licensing architects have been so drawn as seriously to interfere with legitimate engineering practise and the "model law" proposed and advocated by the American Institute of Architects contains definitions of "Architecture" and "building" which, should such laws be passed and enforced, would prevent anyone but a "registered architect" from planning or supervising the construction of any structure or any of the appurtenances thereto; consequently under this head would come a structure having simply foundations and girders, whether "with or without appurtenances." Under this model law proposed by the American Institute of Architects no one but a registered architect shall prepare plans for or supervise the construction of a building, and a "building" is thus defined in Section 19:

"A building is any structure consisting of foundations, floors, walls, columns, girders, and roof, *or a combination of any number of these parts*, with or without other parts or appurtenances."

Since none but a registered architect shall have the right to design or supervise the construction of any structure or any *appurtenance thereto* this matter becomes of vital importance to mechanical, electrical, sanitary and mining engineers, as well as to structural engineers.

In the State of Illinois a similar law for licensing architects was passed several years ago, the rigid enforcement of which made it necessary for engineers to unite in having a "structural engineers' license law" passed by the legislature, and now there are two laws in force in Illinois, one for architects, the other for structural engineers.

In some states the laws enacted and proposed are intended to regulate the practise of architecture, while in the other states laws have been enacted the purpose of which is simply to protect the term "architect," but not intended to regulate the practise of architecture. In Wisconsin and several other states no one may use the title "architect" without first obtaining from the state a certificate of registration as a "registered architect," but anyone not an architect may prepare plans and supervise construction provided he does not style himself an "architect."

Therefore this committee at its meeting of October 13, 1919, adopted unanimously the following resolution:

Motion: the following is the sense of this committee relative to the desirability of a law licensing or registering engineers:

Resolved: The enactment of legislation to provide for the registration of professional engineers is desirable and necessary. Ten states have already enacted such legislation. Laws licensing architects have been enacted in several states and similar laws endorsed by the American Institute of Architects, are pending in several other states, which, if enacted, would prohibit engineers from continuing their customary and recognized practise. . . . Carried unanimously.

†California, Colorado, Florida, Idaho, Illinois, Louisiana, Michigan, Montana, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, South Carolina, Utah, Washington, Wisconsin.

This committee has made a very careful study of definitions for "engineer," "engineering," "architect" and "architecture," but it was found that any definitions for engineering would be so general as to include too much, or too specific to be sufficiently general, or too voluminous to be suitable to incorporate in a law. Some have endeavored to include in a definition of "engineering practise" all sorts and kinds of construction work, but engineering includes investigations as well as plans and no catalogue can well be prepared sufficiently detailed to include all sorts of engineering activities. Several definitions are included in the appendix to this report, and it will be seen that both engineering and architecture are broad terms involving construction and necessarily there can be no sharply drawn distinction. Architects in the broadest sense are engineers even if usually architecture is associated with ideas of artistic or decorative features. Architects are eligible to membership in the American Society of Civil Engineers and several architects are members.

The only basis on which the practise of any profession may be subject legally to state regulation is "in order to safeguard life, health and property." The state may not dictate that no one without a particular kind of artistic talent nor without a tenor voice may practise engineering or architecture, but it may legally require that no one shall practise architecture or engineering that is ignorant of the effects of loads and applied forces or incapable of determining the stresses in structures due to loads and applied forces and unable properly to proportion materials in structures to safely sustain such loads and forces.

Land surveying does not involve matters that would ordinarily jeopardize life and health, but property rights are vitally affected by land surveying, and many states have deemed it essential to place restrictions and safeguards about the practise of land surveying. Land surveying is associated with both engineering and architectural practise.

This commitee has therefore deemed it advisable and to the best interests of all concerned to include in one law, provisions for the registration of engineers, architects and land surveyors. It has recognized that the practises of engineering and architecture overlap in many instances, especially in connection with the larger projects of modern structures, where many branches of the arts and sciences are combined, involving architecture, structural, mechanical, electrical, sanitary, and other lines of engineering. There are ample reasons why architects alone should judge as to the qualifications of those desiring to practise architecture and why engineers alone should pass upon the qualifications of those desiring to practise engineering. Hence a bill for legislation has been drafted by the committee along these lines and it is confidently hoped that the objections expressed by the American Institute of Architects against laws which might provide jointly for the registration of engineers and architects will be overcome by the terms of the bill herewith submitted.

In fixing the qualifications for registration in our proposed bill, these have been purposely made high, but they have not been made unnecessarily difficult for reasonably competent men to meet. It is not intended that candidates would ordinarily be subjected to written examinations, but rather that the board of registration would pass upon the sufficiency of the professional record of each candidate. Minimum qualifications have been clearly set forth which must be met. In order to enable the board to pass upon candidates fairly, certain qualifications are specified as "prima facie evidence of fitness" which (unless other facts derogatory to a candidate are also in evidence) will permit the board to pass the candidate. This so called "prima facie evidence" is not required, but if the candidate can present such evidence his application is the more readily passed upon. For instance, a candidate need not be a graduate of a college of engineering or architecture, but if he is, it is to his advantage. Likewise a candidate need not be a full member of one of the national technical societies or institutes, but if he has won such full membership it is greatly to his professional advantage.

In the preparation of this bill an experienced research engineer, Capt. Raymond J. Roark, was first employed to assist the chairman and a preliminary draft prepared, based upon a comprehensive study of all the data and existing and proposed legislation available. This draft was then discussed and revised by the three Chicago members of the committee, Messrs. Arnold, Alvord and Condron, and the Chicago member of Council, Mr. Loweth. It was then sent to each of the fifteen members of the committee for comments and amendments. After these communications had been received by the chairman and had all been collated a meeting of the entire committee was called and held in Chicago, attended by eight members, Messrs. Arnold, Dunlap, Condron, Shenehon, Slater, Snyder and Woermann, and Mr. Loweth, of Council.

Fourteen sessions were held in the five days, with a stenographic reporter present and all of the communications, as well as additional data gathered by the Chairman, were carefully studied and a complete revision of the original draft made, which draft met the unanimous approval of all the members in attendance. This later draft was carefully edited and sent to the entire committee for approval or amendment, subject to a final editing by the chairman and Mr. Shenehon.

The committee unanimously approved the bill as sent out with minor suggestions for guidance in the final editing. This editing is now completed and the bill is submitted to Council, with this report and with the recommendation that Council approve and endorse the same as a bill for an act of legislation in each and every state, for the regulation of the practise of engineering, architecture and land surveying.

Respectfully,
Committee on Licensing,
T. L. Condron,
Chairman.

Members who are interested can obtain copies of the proposed bill by addressing Secretary Alfred D. Flinn, Engineering Council, 33 West Thirty-ninth Street, New York.

CURRENT ENGINEERING TOPICS

ANNUAL APPROPRIATIONS FOR TOPOGRAPHIC MAPPING

As the time for consideration of Departmental estimates for next year's Sundry Civil Appropriation Bill approaches, the National Service Committee of Engineering Council in cooperation with all state-geologists is urging prominent engineers in every Congressional district to bring pressure to bear upon their Congressmen. This has been accomplished by selecting a prominent engineer,—members of the founder societies in each Congressional district, and directly appealing them to request their Senators and Representative to support a $600,000 appropriation for topographic mapping.

The state-geologists have cooperated by sending these engineers complete information of the local conditions, so that they may be thoroughly conversant with their "back-home" requirements, and thus be more forceful with their men in Congress. Further, most of the state-geologists are endeavoring to get increased state appropriations for this important work, which will have to be matched by an equal Federal appropriation in most cases before they become available for expenditures.

The estimates submitted by the Secretary of the Interior call for an increased mapping program to cost $600,000 annually, instead of $500,000 which was last year's estimate. It will be recalled that the last Sundry Civil Appropriation Bill provided $375,000 for topographic mapping, which was less by $50,000 than pre-war annual appropriations for this work. This year's estimate contemplates a program that will complete topographic mapping in twelve years instead of one hundred years which will be required if the old appropriation is not increased.

NEW CHIEF OF ENGINEERS CORPS, U. S. ARMY

Announcement has just been made that Colonel Lansing H. Beach was appointed by the Secretary of War as Chief of Engineers. While Colonel Beach is best known for the work he has done in connection with Mississippi River projects, he has had the varied service which comes to all Engineer Corps officers who have spent most of their lives in its service. He has done extensive engineering work on Great Lake projects and was in charge of the important improvements of the harbors of Baltimore and Jacksonville. More recently he has been stationed at Cincinnati in charge of the construction of the system of locks and movable dams being constructed in the Ohio River. Colonel Beach has been prominently identified with the development of inland waterways as a member of the Mississippi River Commission, as a member of the Board of Engineers for Rivers and Harbors, and as an advisor to the Waterways Division of Railroad Administration.

TECHNICAL WORK AT THE BUREAU OF STANDARDS

Bulletins dated January 9th on the progress of experimental work that has been started at the Bureau of Standards are as follows:—1. Accuracy of Electrical Measuring Instruments. 2. Electron Tubes in Radio Telephone Transmitting Sets. 3. Recent Radio Publications. 4. Industrial Safety Standards. 5. Measurement of Thermal Expansion of Various Materials. 6. Service Tests of Concrete Floor Treatments. 7. Consistency and Time of Set of Neat Cement Determined by New Method. 8. Slag as an Aggregate for Concrete. 9. Flat Slab Investigation. 10. Manufacture of Automobile Crankshaft. 11. Investigation of Electric Welding. 12. Investigation of Chilled Iron Car Wheels.

Because of the current nature of these investigations the results are not generally put in printed form but complete data on the results of the work to date are always available on application to the Bureau of Standards or the National Service Committee in the Washington office of Engineering Council.

NEW BOARD OF SURVEYS AND MAPS

An executive order signed by the President December 30th created a Board of Surveys and Maps to coordinate the map-making activities in all branches of the Executive Departments. The exact text of this order follows:—

> "In order to coordinate the activities of the various map-making agencies of the Executive Departments of the Government, to standardize results, and to avoid unnecessary duplication of work, I hereby constitute a Board of Surveys and Maps, to be composed of one representative of each of the following organizations:—
>
> 1. Corps of Engineers, U. S. Army
> 2. U. S. Coast & Geodetic Survey, Department of Commerce
> 3. U. S. Geological Survey, Department of Interior
> 4. General Land Office, Department of Interior
> 5. Topography Branch, Post Office Department
> 6. Bureau of Soils, Department of Agriculture
> 7. U. S. Reclamation Service, Department of Interior
> 8. Bureau of Public Roads, Department of Agriculture
> 9. Bureau of Indian Affairs, Department of Interior
> 10. Mississippi River Commission, War Department
> 11. U. S. Lake Survey, War Department
> 12. International (Canadian) Boundary Commission, Dept. of State
> 13. Forest Service, Department of Agriculture
> 14. U. S. Hydrographic Office, Navy Department.
>
> The individual members of this Board shall be appointed by the Chiefs of the various organizations named and shall

serve without additional compensation. The Board is directed to make recommendations to the several Departments or to the President for the purpose of coordinating all map-making and surveying activities of the Government and to settle all questions at issue between Executive Departments relating to Surveys and Maps in so far as their decisions do not conflict with existing laws.

This Board shall perfect a permanent organization and shall hold meetings at stated intervals, to which representatives of the map-using public shall be invited for the purpose of conference and advice.

This Board shall establish a central information office in the U. S. Geological Survey for the purpose of collecting, classifying and furnishing to the public information concerning all map and survey data available in the several Government Departments and from other sources.

All Government Departments will make full use of the above Board as an advisory body and will furnish all available information and data called for by the Board. So much of the Executive Order of August 10, 1906, as grants additional advisory powers to the United States Geographic Board is hereby rescinded and these additional powers are transferred to the Board of Surveys and Maps.

WOODROW WILSON.

The White House
30 December, 1919"

The provision that the Board was to set up a permanent organization was carried into effect on January 13th when representatives from each of the above Departments met and elected O. C. Merrill, Chairman,—Chief Engineer, Forest Service, Department of Agriculture; William Bowie, Vice Chairman —Chief, Division of Geodesy, Coast & Geodetic Survey, Department of Commerce,—and Colonel C. H. Birdseye, Secretary,—Chief Geographer, Geological Survey of the Department of Interior.

It is hoped that this concentration of mapping work will permit larger proportionate appropriations for the country's mapping program under the direction of the Geological Survey. In bringing this matter to the attention of the President, Engineering Council realized the great value of making reliable maps of the whole country available to every branch of the engineering profession in the simplest and most direct way. This will be accomplished through the central information office provided in the Geological Survey to receive and distribute Government and public map data. Thus, if proper appropriations can be obtained and put to work under the Geological Survey, the engineers of the country as well as the Government departments will be greatly benefited.

CHARLES WARREN HUNT

APPOINTED SECRETARY EMERITUS OF A. S. C. E.

At the meeting of the A. S. C. E. Board of Direction of January 21, Dr. Charles Warren Hunt, who had served as Secretary of the Society for 25 years, and who had asked to be relieved from further active duty, was appointed to the newly created office of Secretary Emeritus, the appointment to take effect upon the election of his successor.

Dr. Hunt was born in New York City in 1858 and graduated from the New University in 1876. For sixteen years he was engaged in the practise of Civil Engineering until 1892 when he became Assistant Secretary of the American Society of Civil Engineers. Three years later he was elected Secretary of the Society, which office he has held for the past 25 years. During his term as Secretary the membership has grown from 1800 to 9400.

NOTES FROM NATIONAL RESEARCH COUNCIL

The Carnegie Corporation of New York has announced its purpose to give $5,000,000 for the use of the National Academy of Sciences and the National Research Council. It is understood that a portion of the money will be used to erect in Washington a home of suitable architectural dignity for the two beneficiary organizations. The remainder will be placed in the hands of the Academy, which enjoys a federal charter, to be used as a permanent endowment for the National Research Council. This impressive gift is a fitting supplement to Mr. Carnegie's great contributions to science and industry.

The Council is a democratic organization based upon some forty of the great scientific and engineering societies of the country, which elect delegates to its constituent Divisions. It is not supported or controlled by the government, differing in this respect from other similar organizations established since the beginning of the war in England, Italy, Japan, Canada, and Australia. It intends, if possible to achieve in a democracy and by democratic methods the great scientific results which the Germans achieved by autocratic methods in an autocracy while avoiding the obnoxious features of the autocratic regime.

The Council was organized in 1916 as a measure of national preparedness and its efforts during the war were mostly confined to assisting the government in the solution of pressing war-time problems involving scientific investigation. Reorganized since the war on a peace-time footing, it is now attempting to stimulate and promote scientific research in agriculture, medicine, and industry, and in every field of pure science. The war afforded a convincing demonstration of the dependence of modern nations upon scientific achievement, and nothing is more certain than that the United States will ultimately fall behind in its competition with the other great peoples of the world unless there be persistent and energetic effort expended to foster scientific discovery.

NATIONAL PUBLIC WORKS DEPARTMENT ASSOCIATION

The convention of the National Public Works Department Association was held in Washington, D. C. January 13 and 14, 1920, at the Willard. There were 95 delegates present representing societies with a membership of 90,000. The convention was a very optimistic one, and the measure advocated has developed an unexpected strength.

Chairman M. O. Leighton opened the meeting with a brief address, during which he said:

Our Government has always been wasteful in the conduct of its business. This has not been the result of any wrongful intent. Throughout a long period of years it has been accepted by the majority and the occasions have been sporadic when much thought has been given to it. Wealth usually begets thoughtlessness as to small wastes. So long as our bank balance is large we are not likely to be vigilant as to the price we pay. A few cents more per pound, a few dollars more per yard are paid without thought or hardship. And this was particularly true with respect to Government expenditures when we lived under an indirect system of taxation. Waste of ten million dollars by the Government was hardly appreciable when spread over the price of 10 million pounds of sugar, 10 million pounds of wool and millions of pounds of everything else that we bought in the open market. But now our system of taxation is direct. Every individual of more than nominal earning capacity is presented by the Internal Revenue Office with a bill for his share. And when our annual peace-time budget runs up to $5,000,000,000, as presented by the Secretary of the Treasury a few days since, we begin to think about that leakage.

That five billion dollar estimate will be pruned—severely pruned. That means that we must go without some things that wise and prudent men think we need or that it would be to our advantage to have. Are we then so poor as all that?

No one believes that we are, and yet our bill is so large that it pinches us to pay. The answer is that we are paying too much for what we get. The appropriations committees in Congress will spend the greater part of their time for the next three or four months in pruning those estimates—a laudable and necessary thing to do under the circumstances. But those hard-working men are saving at the spigot and wasting at the bung-hole. We here assembled are asking them to do the obvious thing. Give the Government a business-like organization. Coordinate the functions so that the processes of Government business shall dove-tail. Cut out the wastes and the duplications. Abolish the rivalry between departments. We advocate a Department of Public Works not merely to secure technical symmetry in our Federal organization, desirable as that end may be. Our advocacy is in its essential features an attempt to stop some of these leaks.

When this organization was set up at Chicago I think that none of us—certainly not the speaker—had an adequate idea of the scope of the movement. We saw a loose and inefficient public works organization, divided and sub-divided into many different provinces. As technical men we knew how organically wrong that was. Of the wastes and inefficiencies we were well aware. With the necessity for a coordinated structure, by virtue of which the technical and semi-technical fields of the Government could be rendered efficient and business-like we were profoundly impressed. But that our effort, our idea, our legislative bill would become the cornerstone of a structure embodying efficiency in all Departments of Government we could hardly foresee. As an organization our effort is still focused on a Department of Public Works and that alone. But we realize that with that principle established—that example set—reform in other provinces of Government business activity will occur by the mere logic of events. We are pioneers.

This is the reason why our project for a Department of Public Works strikes straight home to the business man, the manufacturer, the contractor and the merchant, all of whom are represented here today. The technical men who met at Chicago last April to set up this organization built better than they knew. While the project retains all the virtues that appealed to us when it was launched—of technical excellence, of rational government organization, of economy and efficiency, we now see that it reaches to National and to business prosperity, to the fiscal welfare of the Nation, to the individual welfare of the productive business.

Roll call of states on the status of the campaign showed much effective work had been done. It became apparent that the less crowded states had done the most successful work. Two states reported that their entire Congressional representation were committed to this measure.

The Jones-Reavis Bill was discussed and several objections raised to it, especially to the provisions transferring the Bureau of Education to the Department of Labor. The Convention adopted the following resolution to define its position on this subject and on other controversial sections, such as that providing for the transfer of the Forest Service from the Department of Agriculture.

This resolution is as follows:

1. The National Public Works Department Assn. must, under its articles of organization, confine its efforts solely to the creation of a Department of Public Works.

2. Section 3 of H. R. 6649—S. 2232 (the Jones-Reavis Bill) has nothing to do with public works. The only reason for its presence in the bill is that some departmental disposition must be made of the non-engineering bureaus in the Interior Department.

3. It is manifest that the numerous organizations which became affiliated under the name of National Public Works Department Association for a common public works purpose do not, by so doing, commit themselves with respect to any other question, national or otherwise. Therefore each affiliated organization may have and is entitled to express its views as to said Section 3 of the bill without in any way qualifying its approval of the remainder of the bill.

4. The National Public Works Department Association, as such, is therefore unable either to approve or to disapprove the specific assignments of bureaus in the said Section 3, and in advocating the bill before committees of Congress the agents of this Association are to be instructed to present this fact in an unmistakable way.

5. The National Public Works Department Association suggests to all affiliated organizations that they present to Congress their own individual views with respect to said Section 3, either through the legislative agents of this Association or otherwise.

6. The officers and directors of this Association are instructed to have the foregoing statements printed in suitable form and circulated as one of the campaign documents issued in support of this movement.

An address from Governor Frank O. Lowden "On What a Department of Public Works has done for Illinois" was read by Mr. Isham Randolph of Chicago. The meeting then adjourned and the delegates were organized into state teams preparatory to going to Congress the next day to interview their Senators and Congressmen.

The evening session was devoted to speeches by Congressman C. Frank Reavis of Nebraska and by Brigadier General R. C. Marshall, Chief of the Construction Division of the Army.

The Wednesday morning session was devoted to visiting Congressmen and Senators at the Capitol.

At two o'clock the Convention reconvened and roll call by states was taken on the results of the delegates' visits to their Congressmen. It was at once evident that the delegates had met a very pleasant reception and had encountered a real interest in this measure. The most common objection to it was the difficulty of getting new legislation on the calendar during this already crowded session. The Chairman of the Convention pointed out, however, that the Congressional calendar was always crowded, but that time was always found for those measures which Congress believed were demanded by the people.

The uniformly favorable reports from the state committees made the Convention feel that real progress had been made and that the real obstacle in the way was the inertia of the men who should be actively supporting this measure.

The question of finances was then discussed at some length. It developed that the Societies have made very small contributions to the support of this Association and that it has been supported by the contributions of individuals. The Committee recommended that each participating society be asked to assess their members at least one dollar ($1) per man. The Finance Committee notified the Convention that the need of money was acute and must be promptly met.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities, is given below, together with the addresses as they now appear in the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

Robert A. Allen, 390-22nd St., Milwaukee, Wis.
Robert F. Arnott, Amer. District Steam Co., No. Tonawanda, N. Y.
P. K. Chan, Canton Christian College, Canton, Ohio.
C. R. Collins, 506 Hanna Ave., Aberdeen, Washington.
Albert S. Crockett, U. S. Submarine Base, New London, Conn.
Duncan C. Douglas, Public Service Electric Co., Camden, N. J.
Leonard W. Egan, Elec. Furnace Co., Alliance, Ohio.
John Mc F. Fisher, Arapoho, Oklahoma.
G. Foung, Wedgeway Bldg., Schenectady, N. Y.
Jason L. Frye, Camp Kearny, Cal.
J. P. Gailunas, 100½ Can Couvor Ave., Detroit, Mich.
Albert Kalin, City Light Dept., Seattle, Washington.
Lionel D. Leonard, 681 Fifth Ave., New York, N. Y.
Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.
George L. Sewell, Porter Bros., Norfolk, Va.
Bertrand Smith, Kellogg Hotel, Kellogg, Idaho.
Wm. A. Street, Gatun, C. Z.
Lieut. W. J. Strieby, 34 Simpson Road, Ardmore, Pa.
Lieut. T. W. Swartz, 53D Infantry, Chattanooga, Tenn.
A. S. Touche, 72 W. Adams St., Chicago, Ill.
R. M. Umberger, 504 W. King St., Lancaster, Pa.
James A. Young, 2504 Milan St., New Orleans, La.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

SERVICES AVAILABLE

YOUNG MAN; age 25, associate member desires position as Sales Engineer with headquarters at Louisville, Ky. with reliable company handling electrical equipment; has had operative, installation and selling experience and is full of energy; present salary $200 per month. What offers to live wire, clean cut young man in this territory? E-2030.

MOTOR DRAFTSMAN AND DESIGNER; age 30; married; desires change; 12 years' experience on motors, generators and electrical appliances. Services available at once. E-2031.

TECHNICALLY TRAINED ENGINEER; with eight years' experience in construction department of electric public utility corporation, now having immediate supervision of its drafting and engineering office desires change. Age 37, married. E-2032.

MR. MANUFACTURER. How much is this man's service worth to you? Age 34, technical education, Alexander Hamilton Institute business course, Emerson efficiency and scientific management course, 15 years' practical experience as shop foreman, production manager, designer of electrical machinery and purchasing agent; some sales experience. Willing to invest some capital if necessary. E-2033.

ELECTRICAL ENGINEER; University graduate; age 30; married; Two years Westinghouse test and service work, three years engineering construction experienced in power application; installation and operation, electrical test and service; desires position as electrical engineer in electrical power company or in electrical railway service. Location—Middle West or vicinity of New York. Salary $3,000. E-2034.

ELECTRICAL ENGINEERING GRADUATE; Columbia 1910. Experience; 1 year, Test Department of electric lighting company; 7 years, laboratories for testing electrical household devices; 1½ years' practical engineering with large traction company. Desires position in or near New York as sales or industrial engineer with good opportunity for advancement. Salary $2500—$3000. E-2035.

EXPERIENCED TEACHER AND EXECUTIVE; now head of department of electrical and mechanical engineering in one of the larger western universities, is available for suitable opening. Location—immaterial, but position must offer opportunities for growth and service. Confidential correspondence invited from anyone interested. E-2036.

EXECUTIVE ENGINEER; over ten years' experience on construction, maintenance operation, sales, and management of hydro-electric concerns, covering generation, transmission, and distribution of voltages from 110 to 60,000. Location Chicago or Europe. E-2037.

ELECTRICAL ENGINEER; age 37, ex-Professor last two years in engineering department of manufacturing company; would like to correspond with or meet man who can effectually use man of my training and experience. Salary approximately $4000. Kind of work, of little importance so long as engineering training and experience can function. E-2038.

DEVELOPMENT ENGINEER; age 36; thoroughly grounded in shop practise and having ten years' experience in the design of acoustic apparatus. Can show exceptional record of inventive ability. Salary $5000. E-2039.

SUPERINTENDENT OF POWER; or Chief Electrician; age 33; 15 years' practical experience on high and low-tension apparatus, switching equipment and transformer stations. Last four years in charge of construction and maintenance, large industrial plant. Available on short notice. Minimum salary $2400. E-2040.

YOUNG MAN; age 29; married; thorough practical experience as electrical contractor and in handling men; technical training and years of mechanical experience, desires position as electrical superintendent or assistant with reliable firm or as estimator with chance for advancement. Available July. Location—New England States. Salary $2500.00. Address: P. O. Box 107, Erie, Pa. E-2041.

ELECTRICAL ENGINEER; University graduate, Lieutenant Signal Corps; thorough business training; experienced in installation of motors; lightning arresters; wireless apparatus and military telephone systems; two years with power company in operation and maintenance work; one year research on methods of testing desires position as engineer or executive with power company or manufacturer. E-2042.

AMERICAN, TECHNICAL GRADUATE; nine years General Electric Company shop and traveling engineering experience, electrical and steam turbines, desires foreign traveling position for consulting electrical engineers or electrical manufacturing corporations, British possessions preferred. Member, competent, age 32; single, considering change about June first. E-2043.

ELECTRICAL ENGINEERING GRADUATE; 1917 B. S. degree; age 26; married, two years' experience in outside plant engineering of Bell Telephone System, desires position with hydro-electric concern in the design of transmission lines and substations. West preferred. Available on 30 days' notice. Salary $2000. E-2044.

ELECTRO-MECHANICAL DEVELOPMENTAL ENGINEER; of nine years' experience with induction apparatus and ignition systems, desires a permanent connection. Member A. I. E. E. and Assoc-Member A. S. M. E. Salary about $5000. E-2045.

WORKS ELECTRICAL ENGINEER; 5 years' experience; G. E. test, Manufacturing, industrial engineering, power plant design and operation; technical graduate; age 30; married; desires position along consulting or industrial engineering lines. Salary $2500. E-2046.

EX-ARTILLERY MAJOR; 12 years' experience in construction operation and maintenance of large high voltage steam and hydro-electric systems, also experience in irrigation and making reports; university education; desires position in Latin America or India. Knowledge of language, conditions, and labor of both countries. Now receiving $4000. E-2047.

CAPABLE EXECUTIVE; management, production or industrial engineer. Graduate M. E. and business training. Age 32; Twelve years' experience includes; draftsman, Allis-Chalmers shop apprenticeship, factory inventory and appraisal, power plant tests, superintendent of construction, superintendent 600 miles of trolley and transmission lines, chief engineer large industrial corporation, and superintendent research division. Salary $4200. Available 30 days. E-2048.

RESPONSIBLE ENGINEER; Graduate C. E.; married; age 33. 12 years' experience; supervisory work with well-known organizations on broad range of large power station, hydraulic, industrial plant and building work, both from office and construction standpoints. Capable on investigations, reports, business and executive relations. Minimum salary $4200. E-2049.

SALES ENGINEER; technical graduate in electrical engineering; 4 years' experience with manufacturing company of which all but four months has been on sales work. Available on reasonable notice. E-2050.

ELECTRICAL ENGINEER; age 27, experienced in electric railway and industrial plant engineering and electrical installations aboard ships, desires position in either sales or engineering department of concern offering good chance for advancement. Now in charge of design work (electrical) for freighters and tankers. Available on short notice. Salary $3000. E-2051.

TECHNICAL GRADUATE; 2 years Westinghouse test, 2 years responsible construction work with large operating company, 2 years Superintendent of power company in city of 70,000, available on two months' notice as Manager of Power Sales or Assistant to General Manager of Power Company. Salary $3000. E-2052.

ELECTRICAL AND MECHANICAL ENGINEERING GRADUATE; twelve years' experience including Allis Chalmers and General Electric tests, central station engineering, and commercial work with General Electric Company; chief engineer large hydro steam transmission company; age 35; available immediately; E-2053.

MECHANICAL ENGINEER; graduate; age 27; single; 4 years engineering department, large eastern public utility on design, construction and estimating of electrical structures and equipment for generating and substations, desires position with manufacturing concern where more rapid advancement to greater responsibility exists; employed; ex-service man; available on two weeks notice. E-2054.

GRADUATE ELECTRICAL ENGINEER; married, age 37, desires change from present position. Prefers construction or operation in Far East if salary justifies; although willing to go anywhere. Has had factory experience, central station operation, construction and executive experience with Westinghouse. At present engaged in operation and construction heavy electric railway work. E-2055.

ENGINEERING GRADUATE; E. E. and A. M.; desires position with corporation that wishes to establish electric power plants or manufacturing companies in Turkey. Knows conditions in Near East. In addition to English knows French, Turkish and German. 3 years with large electric operating Company in New York City, 1 year teaching Electrical Engineering in large American University. Can start trip in one month. E-2056.

ELECTRICAL ENGINEER; desires position with manufacturer of fractional horse power motors. Seven years' experience in design and manufacture; three years' in charge of production and design. Salary $4000. per annum. E-2057.

PRACTICAL ELECTRICAL MAN; Associate, with some technical training; capable of holding position as division superintendent for central station company or as supervisor of electrical construction; can estimate, layout or supervize installations of power plants or complete factory equipment of any size. Location preferred vicinity Pittsburgh or Baltimore. Present salary $3800. E-2058.

ENGINEER; experienced electrical design, construction and operation power plants and electrical equipment—inside and outside work; overhead and underground, private and public utility plant. Technical graduate, age 35, available March 1st; Salary $300 per month. E-2059.

SUPERINTENDENT OF POWER; with 18 years' experience in construction, operation and maintenance of steam and hydro-electric plants, high tension transmission systems, and distributions; desires position with either a construction company or an operating company. Also familiar with the commercial end of the work. E-2060.

YOUNG MAN, 23, energetic and ambitious, electrical engineering graduate 1919 with B.S. degree, desires position in engineering department of firm where he is given an opportunity to advance according to ability shown. Have had 2½ years' experience as draftsman. E-2061.

ELECTRICAL AND MECHANICAL ENGINEERING GRADUATE; age 26, associate; two years' experience testing and inspecting electrical devices; one year on experimental development work; desires permanent position with opportunity for advancement. References regarding ability available. New York or vicinity preferred. Available immediately. Salary expected $1900. E-2062.

ELECTRIICAL ENGINEER; M. I. T. 1909, age 34, married, open for engagement as sales, consulting or developing engineer, ten years of exceptional broad experience in design, construction, operation, maintenance, testing and machine and process development engineering. Salary $4,000 to $5,000. Available on short notice. E-2063.

EXECUTIVE; with broad engineering training; construction and operating experience; 15 years in hydro-electric and kindred industries. War work:—designed, built and successfully operated large American and British munition plants. Good organizer and handler of men; familiar with modern manufacturing practise. Age 38; American. E-2064.

GRADUATE ELECTRICAL ENGINEER; (1914) desires position in engineering department of growing industrial concern or consulting engineering firm. 3½ years' experience with large public utility in design and layout of outside plant; 2 years with consulting engineers, handling public utility problems. Age 28, single. Available on short notice. E-2065.

ELECTRICAL ENGINEER; Nineteen-sixteen Mass. Inst. of Tech. graduate; recently discharged officer, Engineer Corps; eighteen months experience in rate research, valuation and cost engineering; desires position with firm of consulting engineers making financial and engineering investigations or with institution which finances public utility developments. Minimum salary $2400. E-2066.

TECHNICAL GRADUATE; with 2½ years broad practical experience in power installations for industrial plants. Complete experience from boiler room to engine room, high and low tension distribution, lighting, motors and their equipment. Above experience obtained as mechanic in construction and maintenance and as operator. References furnished. E-2067.

EXECUTIVE ENGINEER with rich mechanical and electrical experience in design and construction of special machinery, also quantity production electrical machinery; desires position as General Manager of manufacturing concern. Has done considerable organizing, systematizing and development work. Graduate in Electrical Engineering. Age 33. Available soon. E-2068.

ENGINEERING GRADUATE, GE testman, experienced in hydro and steam generation, oil and coal fuels. Twelve years experience, master mechanic and chief electrician, gold, silver, quicksilver and coal mining and mill treatment. Desires charge, mechanical and electrical equipment of mining company in western states. Salary $250. E-2068.

OPPORTUNITIES

ELECTRICAL ENGINEER with first class experience in both large and small transformer engineering. Would go into transformer engineering department of large manufacturing company as assistant engineer. Duties will include much special development work. Location Indiana. R-2447.

GENERAL MANAGER for company manufacturing complete line rubber covered wire ranging in size from lamp cord to mining machinery cable. Applicant must thoroughly understand business. Company's financial position and standing in the trade are good. Will sell stock on favorable terms, to experienced and qualified man. R-2453.

ELECTRICAL ENGINEER capable of designing and developing street and commercial lighting fixtures and appliances. Should be able to do drafting as well as designing and should be conversant with construction and line material as well as fixtures. Man with some central station experience preferred. Location Philadelphia, Pa. R-2458.

SALES ENGINEER to open up outside territory for the sale of automobile tires after two or three months training in vicinity of New York City. Some selling experience essential. Man between 30 and 40 years of age desired. R-2459.

ENGINEER; expert in the manufacture of toy transformers. Only man with thorough knowledge of manufacture of large quantities of toy transformers can qualify. Location—New Jersey. R-2461.

EXECUTIVE with accounting experience for work with company manufacturing small machinery parts. Location New York City. R-2462A.

SALES ENGINEERS for commercial application of the product of large manufacturer of electrical equipment. Location Pennsylvania. R-2463.

RESEARCH FELLOWSHIP in acoustics has been established for the encouragement of investigation in this science; at middle western technical institution. Candidates must be college graduates and have at least one year of advanced study in physics. Stipend is $1000 per year. Location Ohio. R-2465.

OPERATING ENGINEER; must be technical graduate with considerable experience in construction, operation and maintenance of hydraulic and steam generating plants and overhead and underground transmission and distribution systems. The present system includes a 20,000 K. W. hydro-electric plant and two auxiliary steam plants, 44,000 volts and 12,000 volt transmission system and 2300/4000 volt distribution system with ten substations. Will have direct charge of operation and maintenance of entire system. Applicant must have had similar work and responsibilities with central station Company. Location Chicago, Ill. R-2493.

ENGINEER OF PLANS AND RECORDS; to take charge of division, the work of which consists of the preparation of plans, specifications and estimates of all additions to or changes in the present generating, transmission and distribution systems, inspection of all work and keeping of records of operation, construction and maintenance. Also necessary that the men be qualified to take charge of operation of system during absence of Operating Engineer. The man for this position must be technical graduate with experience in the design, operation and maintenance of central station systems with some experience in general office methods and systems of records. Must also have experience in the preparation of plans specifications and estimates for work in connection with central station properties. R-2494.

DRAFTSMEN for design of radio apparatus. Position at Radio Laboratories, Camp Alfred Vail, (Little Silver), New Jersey. Pay $2100 to $2500 per annum. Give details as to age, experience and references. R-2505.

MECHANICAL OR ELECTRICAL ENGINEER with experience in the design of radio apparatus to take charge of drafting room. Position at Radio Laboratories, Camp Alfred Vail, (Little Silver), New Jersey. Pay about $3000 per annum. Give details as to age, experience and references. R-2506.

ASSISTANT EDITOR; for *The Electric Journal*, 1204 Keenan Building, Pittsburgh, Pa. Must be a technical graduate, have a pleasant personality, originality and imagination. Young man preferred. Salary dependent upon qualifications. R-2508.

MAINTENANCE ENGINEER to take charge of electrical power plants and steam turbines on phosphate rock producing property. Westinghouse turbines installed. Liberal salary. Location Nichols, Florida. Living conditions reasonably desirable. R-2511.

WELL ESTABLISHED COMPANY in the middle west manufacturing electrical devices, wiring material, outlet and switch boxes, fittings for conduit and armored cable, and the like, wishes to employ competent engineer, with experience in designing such material, to develop additional lines for it to manufacture and to improve its present product. Location Pennsylvania. R-2513.

MACHINE-SHOP DISPATCHER with thorough knowledge of automotive industry pertaining to production work; must be able to assign different jobs and operations to workmen and keep them supplied with necessary material. Excellent opportunity. Location Michigan. R-2524.

RECENT GRADUATES to qualify as chemical engineers, gas operators, electricians, etc. in plant of large manufacturing company. Location Tenn. R-2527.

RESEARCH ENGINEER. Excellent opportunity for right man, with one of the largest concerns of its kind in the United States. Location Chicago. Must be technical graduate with 8 or 10 years of general engineering experience, including designing, experimental engineering, compilation of data, planning and working out of an assigned subject. Must have initiative and tact. Write, giving references, age, experience and salary. R-2529.

YOUNG ENGINEER, technical graduate, to assist in testing and research department. Knowledge of combustion and boiler tests is requisite. In writing give references, experience and age. Location Detroit. Z-21.

INDUSTRIAL RELATIONS DIRECTOR age 30 to 40 years, with about 10 years experience in manufacturing industry, preferably in production work, and about 2 years in employment work; broad guage and high class man wanted. Salary $4000-5000. Location Rochester, New York. Z-22.

SALES ENGINEER for New York City and vicinity. A young engineer, graduate preferred, but essentially a salesman, experienced in selling pumping machinery, steam engines, boilers and general power plant accessories. Good opportunity with progressive organization. Z-53.

DRAFTSMEN WITH EXPERIENCE IN MECHANICAL AND ELECTRICAL LINES, for position with company manufacturing radio and electrical equipment. Salary $35 per week. Location New York State. Z-57.

PATENT ENGINEER; must be a technical graduate and be able to prepare new engineering developments for patent protection. Qualifications: Inventive ability, excellent general theoretical knowledge in chemistry, physics and engineering, as much knowledge as possible of manufacturing and knowledge of patents. Must have ability to take engineer's ideas and expand them into broad patent claims. Excellent opportunity for man of theoretical and scholastic taste. Location Connecticut. Z-60.

ELECTRICAL ENGINEER with technical training to install and supervise operation of A-C. Motors, Steam turbo generator, etc. Salary $275 per month. Location Illinois. Z-66.

ASSISTANT ENGINEER with experience in transmission and differential work for position with company manufacturing automobile gears. Must be thoroughly familiar both with production, manufacture, and operation. Salary $250-300 per month. Location, Ontario. ½ hour from Buffalo. Z-77.

TECHNICALLY TRAINED, EXPERIENCED EXECUTIVE to take charge of a plant manufacturing a line of electrical machinery, both A-C. and D-C. Must be thoroughly experienced along electrical manufacturing lines and be able to guide design as well. Location Chicago, Ill. Z-86.

MAINTENANCE ENGINEER; with about 5 years' drafting experience; will be required to do some drafting as well as set up machines. Mature man desired. Salary $175-$200 per month. Location—New Jersey. Z-95.

ELECTRICAL DRAFTSMAN familiar with layouts, wiring diagrams, etc. for mill and power house work. Work consists of layout for steam and hydro-electric power plants, transmission line work, switchboard layouts, and distribution in mills. Capacity of work runs into thousands of kilowatts in some installations. Man who can make accurate calculations on electrical requirements, work up drawings, and trace them needed. Location New York City. Z-100.

INSTRUCTOR for a 60 hour course on non-textiles to be given in a training school for teachers of retail selling. Course must be non-technical in the sense that it is not meant for workers in any of these lines but for teachers of salespeople who must know their goods from the sales point of view. Location New York City. Z-101.

YOUNG ENGINEER for rating and underwriting of automobile insurance risks for the United States. Must be willing worker, good at mathematics, agreeable and ambitious. Preferable that applicant know something about the various makes of automobiles. Location New York City. Z-108.

SMALL D-C. GENERATOR DESIGNER, with knowledge of costs, sources of supply, manufacturing methods, and ability to compute electrical data, for full or part time work. Must have practical experience. Man acquainted with brush arc type machine preferred. Liberal pay for real expert. Location New York City. Z-110.

INDUSTRIAL ENGINEER; large firm of industrial engineers is constantly on lookout for qualified high grade men. They need not be technical graduates but it would be advantageous. Must have successful executive manufacturing record and be experienced in organization, management, production control, incentives, manufacturing methods and processes, stores control, employment and personnel work and have some knowledge of cost accounting. Should have practical knowledge of operation of machine tools, metal or woodworking or both. Men who have had experience as general managers, works managers, factory managers, superintendents, production managers, etc., are type desired. Applicant would be located in different localities for average of six months at a time. Salary commensurate with ability. Z-111.

FIRST CLASS ELECTRICAL DESIGNING DRAFTSMAN; Salary $250 per month. Location Connecticut. Z-119.

FIRST CLASS GENERAL MECHANICAL DESIGNING DRAFTSMEN for power house and Industrial Plant work. Salary $250 to $275 according to ability. Location Connecticut. Z-120.

CHASSIS TESTER AND INSPECTOR for electric vehicles. Duties to be read testing, mechanical inspection and running in of electric vehicle chasses, as well as inspection of workmanship on chasses and bodies. Location Mt. Vernon, New York. Z-121.

RESEARCH GRADUATE ASSISTANTSHIPS in Engineering Experiment Station of the University of Illinois are open to graduates of approved American and foreign universities and technical schools prepared to undertake graduate study in engineering, physics or applied chemistry. Appointment must be accepted for two consecutive collegiate years, at the expiration of which period if all requirements have been met, the degree of Master of Science will be conferred. Annual stipend $500. For additional information address; The Director, Engineering Experiment Station. University of Illinois, Urbana, Ill. Z-123.

GRADUATE ELECTRICAL ENGINEER for position with company manufacturing cables. Location vicinity of New York City. Z-152.

TECHNICAL ENGINEER with at least two years experience in operation of steam power plants, duties would include estimates, reports and general work of an engineering nature required by large central station and isolated heating plants. Position is in the Steam Engineering Department of a public utility. Location St. Louis, Mo. Z-161.

RECENT GRADUATES of Mechanical or Electrical Engineering courses for engineering work connected with production of electrical and mechanical devices. Send application to Mr. J. C. Wilson, the Cutler-Hammer Mfg. Co. Milwaukee. State training, experience in industrial plants, if any, references and other information concerning yourself. Z-164.

ELECTRICAL ENGINEER experienced in transmission line, substation and distributing construction; preferably one with some power plant construction or operating experience. Man would be Assistant to Engineer in charge of construction work for electric properties which are undergoing rapid expansion. Duties would consist of both office and field work, and cover both design and construction of extensions of the above character. Location Texas. Z-165.

DISTRIBUTION ENGINEER ASSISTANT for underground and substation design. Must be graduate Electrical Engineer. State age, education, experience etc. Location, Middle West. Z-166.

ELECTRICAL ENGINEER GRADUATE with one or two years experience in small motor construction is offered unusual opportunity to qualify for sales force of large motor manufacturing concern. Immediate duties would be to take care of office and of sales in Chicago office and to handle correspondence incident thereto. Resulting familiarity with trade would lead to attractive future. Young unmarried man preferred. Z-167.

ENGINEER for supervising the construction of Hydro Electric Power Plant. Vacancy will call for Resident Civil Engineer to supervise construction, including dam, power station and transmission line. Previous experience on similar work essential. Location Northern Ontario, Canada. Z-186.

SALES ENGINEERS; young men, preferably with mechanical or electrical education and training, although any technical graduate would be considered. Not much sales experience necessary, but men must possess sales potentiality. Salary $150 up depending upon qualifications. Location New York City. Application by letter with which should be enclosed recent snapshot. Z-193.

SALES ENGINEERS; college graduates; some steam engineering experience desirable; must have good personality. Location New York City. Z-198.

RECENT TECHNICAL GRADUATE, with some executive ability, who wishes to take up work in the Engineering Department of a public utility in the Middle West. Salary to start $100, with an excellent opportunity for advancement. Applicant need not have any particular experience, providing he has the capacity for learning. Z-203.

FOREMAN AND ELECTRICAL DEPARTMENT; old established concern, located about 200 miles west of New York City, manufacturing high grade, electro-mechanical devices for low tension service has vacancy for thoroughly experienced Foreman. Must essentially be first-class mechanic, to work accurately to drawings, and specifications; well trained to progressive assembly and first-class workmanship in every detail; good leader of men with qualifications to expand with increasing responsibilities. Position offers exceptional opportunity for advancement. Reply in own handwriting, giving full particulars of experience; references; age; nationality. Replies treated as strictly confidential. Z-210.

POWER-SALESMAN; graduate electrical engineer; familiar with electrical machinery and capable of studying and developing applications for the use of electricity. This is very good opportunity for capable and energetic young man; Location Minnesota. Initial salary $150. Z-214.

JUNIOR ELECTRICAL ENGINEERS: recent graduates, for work with large industrial corporation. Location Massachusetts. R-2328.

TECHNICAL GRADUATES wanted for engineering calculations, drafting and research work in connection with steam turbine design. Leading to engineering positions. Z-229.

FIRST CLASS ENGINEERS AND DRAFTSMEN experienced in design of heating and ventilating systems, power plants, electric wiring layouts, sprinkler systems and plumbing. Salaries range from $200 to $300 per month. In reply state education, experience in detail, salary expected and earliest date you could report for work. Address Smith, Hinchman & Grylls, Architects and Engineers, 710 Washington Arcade, Detroit, Michigan. Z-230.

PERSONAL

DAVID S. WEGG, JR., formerly Inspector of Ordnance, Standard Car Co., Hammond, Ind., has become affiliated with the Chicago office of the Allis-Chalmers Mfg. Co. as sales engineer.

GEORGE E. ARMSTRONG, formerly Protection Engineer with the Southern California Edison Company, is now Associate Editor of the *Journal of Electricity*. His address is 531 Rialto Building, San Francisco.

J. B. HARRIS, JR., has resigned his position as Pittsburgh manager for the Pittsburgh Transformer Company, Pittsburgh, Pa., to become associated with Harris and Evans, District Managers, 902 Real Estate Trust Building, Philadelphia, Pa.

J. R. TEMPLIN, Consulting Engineer of Christchurch, New Zealand, was a visitor at Institute headquarters January 14. He is visiting the United States to obtain information regarding the latest developments in the electrical industry.

CLARENCE GOLDSMITH, who has been engineer for the National Board of Fire Underwriters for the past twelve years and late Major in the Construction Division of the Army, has been placed in charge of the branch engineering office recently established by the National Board at 234 South La Salle Street, Chicago, Ill.

CARL A. BAER, formerly Captain Baer, 56th Engineers, U. S. Army, announces that he has formed a partnership with MERRITT T. COOKE, JR., formerly of the Engineer Corps, U. S. Army, and that the business will be conducted under the firm name of Carl A. Baer & Company, Engineers, with offices in the Land Title Building, Philadelphia.

H. A. P. LANGSTAFF, who has been with the J. G. White Engineering Corporation as Field Electrical Engineer on the construction of the power house involving installation and test of one 60,000-kw. steam turbine for the U. S. Nitrate Plant No. 2 at Mussel Shoals, Alabama, has recently become connected with the West Penn. Power Company of Pittsburgh.

N. G. LINDSTROM, formerly with the S. K. F. Ball Bearing Company, Hartford, Conn., has been appointed by the Roller-Smith Company, New York City, as Works Manager of its plant at Bethlehem, Pa. He is a graduate of the Royal Institute of Technology at Stockholm, Sweden, and since his graduation has had wide experience with electrical and engineering concerns which makes him particularly well fitted to assume his new duties.

WALTER W. GASKILL has been appointed to represent the Roller-Smith Company, New York City, in New England territory. He will handle also products of the Ward-Leonard Electric Company, Mt. Vernon, N. Y., and the Brown Instrument Company, Philadelphia, Pa. From June 1918 until April 1919 Mr. Gaskill was located in Washington with the Bureau of Aircraft Production, his particular work being in connection with the development and production of mobile lighting outfits for the illumination of aviation fields for night flying.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (DEC. 1st–31st, 1919)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

L'ALUMINIUM DANS L'INDUSTRIE. Métal pur Alliages D'Aluminium.

By Jean Escard. Paris, H. Dunod et E. Pinat, 1918. 272 pp., illus., 10 x 6 in., 18 francs. (Purchase.)

The subjects discussed include the manufacture of aluminum, its physical and chemical properties, soldering, the influence of mechanical treatment on its properties, and its applications in metallurgy, electrical and mechanical industries, etc. The constitution, properties and uses of the various aluminum bronzes and alloys of aluminum with various metals, both common and rare, are described, and a final chapter treats of alloys with silicon, aluminum carbides and nitrides, and several alloys for special purposes. The volume gives a concise survey of present knowledge of aluminum.

APPLIED SCIENCE FOR METAL WORKERS.

APPLIED SCIENCE FOR WOOD-WORKERS.

By William H. Dooley. N. Y., The Ronald Press Co., 1919. $2 each.

These volumes present a course in the general principles of science, which gives particular attention to their applications in industry and is intended for use in vocational high schools, industrial schools, apprentice classes, etc.

The general scientific matter in the two books is identical. Additional material relating specifically to the woodworking trades appears in one, while the other treats of metal-working in similar fashion.

BUILDING OF THE PACIFIC RAILWAY.

The Construction-Story of America's First Iron Thoroughfare between the Missouri River and California, from the Inception of the Great Idea to the Day, May 10, 1869, when the Union Pacific and the Central Pacific joined tracks at Promontory Point, Utah, to form the Nation's Transcontinental. By Edwin L. Sabin. Philadelphia & London, J. B. Lippincott Co., 1919. 317 pp., 10 pl., 4 por., 1 map, 8 x 5 in., cloth, $2.

Mr. Sabin's object has been to tell how the Pacific railway came into being; to describe the actual building operations by which the Union Pacific Railroad, from the Missouri River, and the Central Pacific Railroad, from the Sacramento River, were constructed in six years instead of the allotted fourteen. The book is a popular, readable account of the men who built the roads and of the methods used.

CLAY PLANT CONSTRUCTION AND OPERATION.

By A. F. Greaves-Walker. Chicago, Brick and Clay Record, 1919. 212 pp., 79 illus., 9 x 6 in., cloth, $4.

In writing this work the author has attempted to explain in understandable English some of the problems of the manufacturer of structural clay products. Technical terms, formulas, and theories have been avoided, and practical facts alone presented.

ELECTRICAL ENGINEERING PAPERS.

By Benjamin G. Lamme. This volume contains a collection of the author's most important engineering papers presented before various technical societies and published in engineering journals and elsewhere from time to time. 1919. Published by Westinghouse Electric & Mfg. Co. 773 pp., illus., 9 x 6 in., cloth, $2.50. (Gift of author.)

A collection of thirty-one papers and addresses which have appeared in various periodicals during the period from 1897 to 1918. These papers deal with problems of generator and motor design, the history of direct-current generators and of street railway motors, and with technical training. The volume is published by the Westinghouse Electric and Manufacturing Company to commemorate Mr. Lamme's connection with it for thirty years.

ELEMENTARY PRINCIPLES OF AEROPLANE DESIGN AND CONSTRUCTION.

A textbook for Students, Draughtsmen, and Engineers. By Arthur W. Judge. Lond. and N. Y., James Selwyn and Co., Ltd., 1919. 116 pp., 56 illus., 13 tables, 9 x 6 in., cloth, $3. (Gift of Isaac Pitman & Sons.)

Written to provide an inexpensive book, of an elementary nature, dealing with the fundamental principles of the design and, to a certain extent, the construction of airplanes. Follows the plan of the author's larger work, to which it may serve as an introduction.

GUIDE TO THE STUDY OF THE IONIC VALVE.

Showing its Development and Application to Wireless Telegraphy and Telephony. By William D. Owen. Lond., Sir Isaac Pitman and Sons. 59 pp., 12 illus., 6 x 4 in., cloth, $1.

This little volume is intended to provide, for students of radio-telegraphy, an impartial, coherent record of the development of the ionic valve. References to the original sources of the information enable the reader to pursue his study of the subject.

INDUSTRIAL RECONSTRUCTION PROBLEMS.

Complete Report of the Proceedings of the National Engineers. New York City, March 18-21, 1919. 197 pp., 9 x 6 in., paper.

The papers presented at the conference dealt with a wide variety of problems connected with the reorganization of our industries on a peace basis. Consideration is given to questions of finance, commerce, production, labor, education, management, etc.

MACHINE TOOL OPERATION.

Part I. The Lathe Bench Work and Work at the Forge. By Henry D. Burghardt. 1st edition. N. Y., McGraw-Hill Book Co., Inc., Lond., Hill Publishing Co., Ltd., 1919. 326 pp., illus., tables, 8 x 5 in., cloth, $2.

The author of this work has used his experience as a teacher of machine work in a technical high school to prepare a textbook for those who desire a knowledge of the principles and elementary operations of machine shop work, suitable for use in technical and trade schools and in apprenticeship courses. While designed primarily for use in connection with lectures by an instructor, it is also useful for self instruction.

THE MANUFACTURE AND TESTING OF MILITARY EXPLOSIVES.

By John Albert Marshall. 1st edition. N. Y., McGraw-Hill Book Co., Inc., Lond., Hill Publishing Co., Ltd., 1919. 261 pp., 8 x 6 in., cloth, $3.

This volume contains a concise account of the explosives used for military purposes, in which attention is directed to those points which have a direct bearing on the manufacture, testing and storage of these substances. An extensive bibliography is included.

METAL WORKER'S HANDY-BOOK OF RECEIPTS AND PROCESSES.

Being a collection of chemical formulas and practical manipulations for the working of all the metals and alloys; including the decoration and beautifying of articles manufactured therefrom, as well as their preservation. Edited by William T. Brannt. New enlarged edition. N. Y., Henry Carey Baird and Co., Inc., 1919. 582 pp., illus., tables, 8 x 5 in., cloth, $3.

Five new chapters have been added to the present edition of this work, describing methods for welding with the oxy-acetylene flame, thermit and electricity, for galvanizing and for die casting.

MILLIONS FROM WASTE.

By Frederick A. Talbot. Phila., J. B. Lippincott Co.; Lond., T. Fisher Unwin Ltd., 1920. 308 pp., 9 x 6 in., cloth, $5.

This work is written to indicate certain of the most obvious channels through which wealth incalculable is being permitted to escape, as well to describe some of the highly ingenious efforts which are being made to prevent this wastage. While written essentially for the uninitiated, it will, the author hopes, prove of aid to those who are fully alive to the potential values of refuse. The volume is confined to those phases of the subject which are familiar to the average person.

OIL ENGINES. DETAILS AND OPERATION.

By Lacey H. Morrison. 1st Edition. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 472 pp., illus., tables, diagrams, 9 x 6 in., cloth, $5.

This volume is intended for operators of oil engines. The details of construction of the more important oil engines manufactured in the United States are described and the proper methods of adjustment are explained at length.

THE PETROLEUM HANDBOOK.

By Stephen O. Andros. Chic., The Shaw Publishing Co., 1919. 206 pp., illus., tables, 7 x 4 in., flexible cloth, $2.

In a book of pocket size, the author gives the fundamentals of each phase of the oil industry necessary to a clear understanding of the various operations entailed between the location of an oil well and the distribution of the refined products. The work is chiefly a compilation from the standard authorities, arranged for those who wish a brief, accurate account of the industry, devoid of unnecessary detail.

PRINCIPLES OF INDUSTRIAL ORGANIZATION.

By Dexter S. Kimball. 2nd edition, rev. and enlarged. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1919. 325 pp., 21 illus., 1 pl., 12 tables, 9 x 6 in., cloth, $3.

This work, the first edition of which appeared in 1913, has been written to give young engineers a concise account of the salient facts regarding the most important economic and sociological problems with which they will be brought in contact, and to explain the origin and growth of the important features of industrial organization. The present edition has been revised, rearranged and enlarged.

SELENIUM CELLS.

The Construction, Care and Use of Selenium Cells with special reference to the Fritts Cell. By Thomas W. Benson. N. Y., Spon and Chamberlain; Lond., E. & F. N. Spon, Ltd. 1919. 63 pp., 18 illus., 8 x 5 in., cloth, $1.50.

The lack of definite information on the construction of selenium cells has led the author to publish the results of some of his experiments.

After a brief review of various types of cells, the book describes in detail the manufacture, maturing and testing of the Fritts cell, and concludes with an account of some applications and suggestions on the care of cells.

STRENGTH OF MATERIALS.

A Textbook for Technical and Industrial Schools. By John Paul Kottcamp. 1st edition. N. Y., John Wiley and Sons, Inc.; Lond., Chapman and Hall, Ltd., 1919. 193 pp., 103 illus., 19 tables, 8 x 5 in., cloth, $1.50.

The course of instruction presented in this textbook sets forth the fundamental principles with a minimum of mathematics, and shows the application of these principles by a large number of examples which are worked out in detail. The book is based on the author's course in the subject at Pratt Institute.

TECHNISCHER LITERATURKALENDER. 1918.

München-Berlin. R. Oldenbourg, n. d. 640 columns, 1 por., 8 x 6 in., cloth, 12 marks plus 20% increase.

This volume is a concise biographical dictionary of living German authors of technical and scientific books, compiled by the Librarian of the German Patent Office. Over five thousand writers are included. The information given includes their addresses, education, age, occupations, technical specialties, publications, etc.

TECHNO-CHEMICAL RECEIPT BOOK.

Containing Several Thousand Receipts and Processes, Covering the Latest, Most Important and Most Useful Discoveries in Chemical Technology and Their Practical Application in the Arts and the Industries. Compiled and edited by William T. Brannt and William H. Wahl. New enlarged edition. N. Y., Henry Carey Baird and Co., Inc., 1919. 516 pp., illus., tables, 8 x 5 in., $2.50.

The principal aim in preparing this work has been to give a compendious collection of approved receipts and processes of practical applications in the industries. The receipts have been principally derived from German sources and most of them have been tested practically. The present edition has been revised and various receipts added.

WHEN THE WORKMEN HELP YOU MANAGE.

By William R. Basset. N. Y., The Century Co., 1919. 266 pp., 7 x 5 in., cloth, $2.

The author states that, as a result of large practical experience, he has come to the conclusion that right relations between employers and employees depend upon the establishment of arrangements by which both parties may express themselves in their work, without the intervention of outside agencies. In this book he develops certain principles underlying satisfactory relations and gives examples of their successful application by various industrial concerns.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Baltimore.—December 12, 1919, Johns Hopkins University. Paper: "Power for Electro-Mechanical Industries" presented by Professor Richards. The paper was illustrated with lantern slides, and Professor Richards gave a most lucid outline of the methods used by the electro-mechanical industries and of their power requirements. Attendance 86.

Boston.—December 9, 1919, Engineers Club. Paper: "Electric Power Transmission Cables." Speaker: Mr. W. H. Cole. The paper was illustrated by lantern slides. Attendance 125.

December 16, 1919, Cambridge. The Section was invited to participate in a trip and meeting with the A. S. M. E. The party met at the gate of the Watertown Arsenal, Watertown, Mass., and made an extensive tour of the Arsenal under the guidance of the superintendent. On the completion of the trip the party assembled at The Harvard Union, Harvard College, and a part of them made an inspection tour of the Laboratory of the new Harvard Engineering School. At 6:15 dinner was served at Harvard Union. During the dinner short addresses were made by Professors Hughes and Webster. At 8:00 p. m. the party assembled in Emerson Hall, Harvard University, and listened to a talk by Professor Albert Sauveur on "Metallography and Heat Treatment of Metals." Dr. Langenberg also addressed the meeting. Attendance 150.

January 6, 1920, Chipman Hall, Tremont Temple. Subject: "Electric Welding." Speaker: Professor C. A. Adams. Professor Adams' talk was illustrated with lantern slides, and he gave a history of welding and the welding organization. The discussion was participated in by Professor Elihu Thomson, F. L. Fairbanks and others. Attendance 175.

Cleveland.—December 16, 1919, Cleveland Engineering Society. Paper: "The Manufacture and Magnetic Testing of Electric Sheet." Speaker: Mr. W. J. Beck, Research Director, American Rolling Mills Co., Middletown, Ohio. Attendance 95.

Detroit-Ann Arbor.—December 12, 1919, Board of Commerce. Talk by Mr. Esterline. Attendance about 100.

January 9, 1920, Board of Commerce. Joint meeting of Detroit-Ann Arbor Section of A. I. E. E., Detroit Engineering Society and American Society of Mechanical Engineers. Mr. David Hall, of the W. E. & M. Co., gave a talk, illustrated with lantern slides, on "The Design and Application of Electric Propulsion Equipment for Submarines." Attendance about 150.

Fort Wayne.—December 18, 1919, G. E. Co. Bldg. 26-2. The speaker of the evening was Mr. R. H. Chadwick, G. E. Co., who gave a very interesting talk with demonstrations on "High Frequency Phenomena." The apparatus used was very complete. Attendance 40.

Indianapolis-Lafayette.—December 19, 1919, Chamber of Commerce. Mr. John L. Niesse, Big Four Railway Telephone & Telegraph Engineer, discussed modern railroad wire systems. Attendance 30.

Ithaca.—November 21, 1919, Franklin Hall, Cornell University. Subject: "Measuring Instruments and Other Detail Apparatus in a Large Electrical Power Plant," by Mr. H. S. Baker, Ontario Power Co., Niagara Falls; and "Demonstration of a Curve Drawing Instrument" by Mr. W. B. Stover, of the W. E. & M. Co. Mr. Baker discussed the various detail apparatus and protective devices which are necessary to maintain reliable operation and service in a large electrical generating and distributing system, and gave practical examples from the Ontario Power Plant. Mr. Stover demonstrated the Westinghouse graphic voltmeter, and explained the principle of its operation. Attendance 95.

Los Angeles.—December 2, 1919, Auditorium Los Angeles Polytechnic High School. This was a special meeting with several other technical societies participating. Speaker: Dr. Frank B. Jewett. Subject: "Some War-time Developments in Electrical Communication and Allied Fields." Attendance 900.

December 5th, 1919, Choral Hall, Auditorium Bldg. Dr. Jewett explained the technical problems involved in the developments of electrical communication which were brought up in his lecture at the meeting of December 2. Dr. Jewett answered many questions which had been handed in as a result of the previous meeting. Attendance 180.

Lynn.—December 17, 1919, G. E. Hall. Lecture on "Fundamentals of Economics" delivered by Mr. George E. Roberts, Vice-President, National City Bank, New York. Attendance 298.

January 7, 1920, G. E. Hall. Subject: "Manufacture and Uses of Steel." Speakers: Messrs. W. H. Kaup and T. J. Jobson. Attendance 155.

Madison.—December 16, 1919, Assembly Chamber, Capitol. Illustrated lecture by Professor L. S. Smith, of the University of Wisconsin, on City Planning and Zoning. The paper was followed by a discussion of some of the phases of Madison's proposed zoning law. Attendance 25.

Milwaukee.—December 18, 1919, Athletic Club. Subject: "The beginning of a New Lighting Era, or How Fast Can you See?" Speaker: Mr. S. E. Doane, Chief Engineer, National Lamp Works, G. E. Co., Nela Park, Cleveland, Ohio. The speaker used interesting apparatus and lantern slides to demonstrate what a very important factor in production and industrial progress illumination really is. Attendance 160.

January 14, 1920, Athletic Club. Mr. Max Rotter, Consulting Engineer for the Busch-Sulzer Brothers, Diesel Engine Company, St. Louis, gave a very interesting talk on the Diesel engine with particular reference to the two cycle engines. The talk was illustrated. Attendance 140.

Minnesota.—December 8, 1919. Paper: "Electrical Cooking" by Mr. H. E. Kahlert, of the Minneapolis G. E. Co. The speaker gave a history of the development of electric ranges and a description of the various types of ranges now in use. His paper gave information as to demands, load factor and diversity factor of electric ranges for residence, apartment houses and large users, such as hotels. The meeting was preceded by an electrically cooked dinner. Attendance 51.

Panama.—December 6, 1919, Balboa Heights. Mr. C. J. Welcke, of the Electric Storage Battery Co., New York, read a paper on "Storage Batteries, their Construction and Uses," after which a lively discussion took place. Attendance 31.

December 13, 1919, Balboa Heights. Mr. Holmstrom, of the Automatic Electric Co., Chicago, Ill., gave a talk on the Automatic Telephone. A 25 line P. A. X. switchboard was used for demonstration. Attendance 35.

January 10, 1920, Balboa Heights. Subject: "Symposium on Underground Construction." Discussion led by Mr. William T. O'Connell. Messrs. Hersh, Graham, Bleakley, Moffat and Stiles took part. Attendance 12.

Philadelphia.—January 12, 1920, Engineers Club. Subject: "Electric Propulsion of Ships and Submarines." Speakers: Eskil Berg, G. E. Co., and W. E. Thau, W. E. & M. Co. Attendance 132.

Pittsburgh.—January 12, 1920, Chamber of Commerce Auditorium. Subject: "The Application of Electrical Apparatus to Steel Mills." Speaker: Mr. C. E. Stoltz, W. E. & M. Co. Attendance 68.

Portland.—December 9, 1919, University Club. Mr. O. L. LeFever and Mr. A. D. Leach, of the Northwestern Electric Company, presented papers on "Central Station Steam Heating Problems," Mr. LeFever dealing with high pressure transmission and Mr. Leach with low pressure distribution. Addresses were illustrated with stereopticon. Attendance 19.

Seattle.—November 17, 1919, Chamber of Commerce. Subject: "Some War Time Developments in Communication and Allied Fields." Speaker: Dr. F. B. Jewett. Dr. Jewett illustrated his talk with lantern slides and one reel of motion pictures. Attendance 85.

December 16, 1919, Chamber of Commerce. Paper: "Radio Engineering in the Thirteenth Naval District," presented jointly by Mr. R. H. Marriott and Dr. H. H. Lester of the Bremerton Naval Station Radio Laboratory. Dr. Lester outlined the scope of the work done by this district, explained the fundamental principles and circuits, and showed the desirability of the new trans-Pacific wireless route from Keyport to Vladivostock by way of St. Pauls Island on the coast of Alaska. Mr. Marriott gave a description of a method invented by him for guiding ships into narrow, crooked channels and gave a demonstration with experimental apparatus. The method consisted of passing a small alternating current through a cable laid along the desired course in the channel and determining its location by means of the induction in a coil of 2,000 turns of wire arranged so as to be adjustable. The coil is turned until the maximum induction is obtained as determined by means of head phones, when it points toward the cable. Mr. Jefferson, of Kilbourne & Clark, had a one quarter kilowatt radio set of the commercial type on exhibition and gave a demonstration. The main points brought out in his discussion were the simplicity and ruggedness of the apparatus. Mr. Marriott stated that the current used in his tests was seven tenths of an ampere, which was the maximum amount possible with 40-volts, the rating of the cable used. Following the presentation of the paper election of officers for 1920 was held, resulting as follows: Chairman, Mr. G. E. Quinan, Secretary-Treasurer, Mr. W. T. Batcheller. Attendance 65.

Spokane.—December 18, 1919, Davenport Hotel. Luncheon of the Associated Engineers of Spokane in honor of Messrs. H. V. Winchell and Bradley Stoughton. Mr. Winchell told of earlier visits to the West and Mr. Stoughton discussed the proposed bureau of public works and other engineering matters. Attendance 75.

December 18, 1919, (evening) Davenport Hotel. Regular meeting of the Associated Engineers of Spokane under the auspices of the Columbia Section A. I. M. & M. E. Meeting took the form of a dinner in honor of Messrs. H. V. Winchell and Bradley Stoughton. Attendance 84.

Toronto.—December 5, 1919, Engineers Club. Mr. G. A. Burnham gave a most interesting discourse on Circuit Breakers. He went very thoroughly into the points which affect both the design and the selection of circuit breakers as regards rupturing and current carrying capacity. Mr. Burnham also described in detail a new type of circuit breaker designed to take care of the expansion and release of the gases generated by the arc when the breaker opens under heavy load. A number of slides were shown illustrating the different types of circuit breakers for various capacities and voltages. Attendance 109.

December 19, 1919, Engineers Club. Mr. H. Harvie presented an interesting paper giving a summary of the extent and value of the water powers of Canada. The paper was illustrated by lantern slides showing a number of the undeveloped water powers and also some of the hydro developments at present in operation. In the discussion following the paper Mr. P. W. Ellis, Chairman of the Victoria Park Commission, Niagara Falls, gave some very interesting information relative to the Niagara development and the proposed plans of the Commission for extending the parkway system from Queenston to Lake Erie. Attendance 65.

Washington, D. C.—December 9, 1919, Cosmos Club Hall. Subject: "Methods of Studying the Behavior of Heavy Guns When Fired from a Battleship." Speaker: Dr. H. L. Curtis, of the Bureau of Standards. Illustrated by lantern slides. The talk was followed by a short discussion and an interesting talk by Professor C. A. Adams on research work, standardization and related topics. Attendance 110.

January 13, 1920, Cosmos Club Hall. Commander S. C. Hooper, of the Navy Department, gave an interesting talk on "The Present Status of the Radio Art" illustrated by lantern slides. Attendance 135.

PAST BRANCH MEETINGS

University of Arkansas.—January 13, 1920, Y. M. C. A. Hut. General Electric film shown, entitled "Fairy Magic." Attendance 45.

University of Cincinnati.—January 6, 1920. Mr. W. F. Dunkle, gave a talk on "Smoke and Smoke Prevention." Attendance 65.

Clarkson College of Technology.—January 9, 1920. Reorganization meeting with election of officers as follows: E. R. Taylor, Chairman; H. C. Cohn, Secretary; P. F. Hadlock, Treasurer. Attendance 33.

Clemson College.—January 8, 1920 Elec. Engg. Lecture Rooms. Subject: "The Electron Theory." Discussion by Prof. S. R. Rhodes, J. Y. Dunbar and G. E. R. Davis. Life of Millikan, by T. J. Zeigler. Current Events, C. Yongue. Attendance 59.

University of Colorado.—January 15, 1920. Mr. Robert Owen (a student) gave an illustrated talk on "High Tension Insulating Materials." Three reels of film were then shown covering the use of electrical machinery in the manufacture of steel. Attendance 33.

University of Kentucky.—January 15, 1920, Mechanical Hall. Subjects: (taken from A. I. E. E. PROCEEDINGS) "Speed and Output of Single-Shaft Turbo Generators," D. C. Choate; "Transatlantic Radio Communication," J. W. Coleman, Jr.; "Speed and Output of Single-Shaft Steam Turbines," E. E. Elsey; "California 220,000 volt 1100 mile Transmission Bus," U. V. Garred. Attendance 20.

University of Maine.—January 7, 1920, Lord Hall. Mr. A. B. Moulton related some of his personal experiences with the wireless during the war. Mr. Ames gave a talk on his experiences across with the communication engineers. Both speakers are seniors at college at present. Attendance 27.

Massachusetts Institute of Technology.—January 9, 1920. Subject: "Electric Railway Operation." Speaker: J. H. Neal. Attendance 125.

University of Michigan.—January 14, 1920, Natural Science Bldg. The following films were shown: "Queen of the Waves" and "The Electrical Giant." Attendance 40.

School of Engineering of Milwaukee.—December 17, 1919. Paper: "Appraisals and Evaluations." Speaker : Mr. L. H. Olsen, G. M. of the American Appraisal Company. Attendance 50.

University of North Carolina.—December 1, 1919. Talks as follows: "The Mazda Lamp" F. Weitzel; "Smokeless Powder Loading Plant" R. G. Koontz; "Mercury Interrupters" W. K. Harding; "The Cadillac Motor Car Co. Plant" W. H. Horne. Attendance 40.

University of Notre Dame.—December 1, 1919, Engineering Hall. Papers read as follows: "Transatlantic Radio Communication" by James L. Trant and "The Vacuum Tube" by William L. Wenzel. Attendance 25.

December 15, 1919, Engineering Hall. Illustrated lecture on the Phenomena of Induction by Professor J. A. Caparo; The Life and Works of Ohm by A. B. Butine. Refreshments were served after the meeting. Attendance 27.

Ohio Northern University.—December 17, 1919, Dukes Memorial. Subjects: "Power Switchboard Installing" Mr. R. E. Long, and "Automobile Generator Armature Winding" Mr. Olen Coffman. Attendance 80.

January 8, 1920, Dukes Memorial. Subjects: "House Wiring" Mr. R. E. Long and "The Engineer and the Engineer's Exhibit" Prof. F. F. Turner. Attendance 24.

January 15, 1920, K. of P. Hall. Smoker. Attendance 65.

University of Oklahoma.—December 11, 1919. Subjects: "New Inventions and Discoveries" John P. Jones; "Observations in France" Archie Wallace; "Coil Aerials" E. B. Ferril; "New 50,000 Cycle Alternator" W. A. Kitchen. Attendance 21.

University of Pennsylvania.—November 17, 1919. Paper: "Interior Illumination." Speaker: S. Zuchovitz.

December 1, 1919. Papers: "The Development of the Incandescent Lamp" R. A. Hoke, and "Trunk Line Electrification" R. T. Ervin.

December 15, 1919. Papers: "The Manufacture of Wires and Cables" H. James and "Resuscitation from Electric Shock" W. M. Arthur.

January 12, 1920. Papers: "Vacuum Tubes" W. H. J. McIntyre, and "Starting and Lighting of Automobiles" J. M. Ryan.

Stanford University.—January 7, 1920. Business meeting. Attendance 8.

January 14, 1920. Subject: "The Place of the Engineer in Society." Speaker: Dr. David Starr Jordan. Attendance 50.

Syracuse University.—December 11, 1919. Address by Mr. R. E. Greiner on "Electrical Solutions to Economic Problems." Attendance 14.

December 18, 1919. Address by Mr. K. J. Cole on "Rectifiers." Attendance 12.

January 13, 1920. Moving picture film "The King of the Rails" was shown, following which Mr. G. A. Mezger gave an illustrated lecture on "Electrification of Railroads." Attendance 88.

Throop College of Technology.—December 5, 1919. Subject: "Opportunities in Electrical Communication." Speaker: Dr. Frank B. Jewett. Attendance 35.

December 8, 1919. Subject: "Hydroelectric Developments in California." Speaker: Mr. H. L. Doolittle, Engineer, Southern California Edison Co. Attendance 30.

University of Virginia.—January 8, 1920. Professor Shepherd gave an interesting demonstration of overloading a series generator when supplying a lamp load and motor load, and the consequent periodic reversal of the motor's rotation direction, due to the generator overload condition. Attendance 16.

Yale University.—November 25, 1919. Paper: "Some Practical Experiences of an Engineer." Speaker: Mr. Frederic Cutts, General Manager, G. E. Co., New Haven, Conn.

December 9, 1919. Paper: "Some Problems of the Telephone Engineer." Speaker: Mr. L. F. Morehouse, Equipment Development Engineer, A. T. & T. Co., New York, N. Y.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JANUARY 9, 1920

ANTHONY, HARVEY M., Head of Dept. of Applied Electrical Engineering, Muncie Senior High School, Muncie, Ind.

ARNOLD, JAMES C., Partner, Arnold & Frankfurt, 202 Crary Bldg.; res., 5906 8th Ave. N. W., Seattle, Wash.

ASHBROOK, ROY B., Telephone Engineer, Southern California Edison Co., Alhambra, Cal.

ASKUE, ALBERT R., Inspector & Cable Tester, Cleveland Electric Illuminating Co., Cleveland; res., 3144 E. Overlook Road, Cleveland Heights, Ohio.

BALFE, JOHN P., Supt., Power House, Yukon Gold Co., Dawson, Y. T., Canada.

BEISWENGER, OTTO L., Chief Electrical Operator, The Goodyear Tire & Rubber Co., Akron, Ohio.

BENTON, P. E., Wireman, Panama Canal, Balboa, C. Z.

BIRK, JOSEPH W., Lieut., U. S. Navy Dept. of Electrical Engg. & Physics, U. S. Naval Academy, Annapolis, Md.

BISHOP, JOHN, Assistant, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont.

*BITNER, RALPH EMERSON, Engineer, Western Electric Co., 463 West St., New York, N. Y.

*BOWEN, WILLIAM C., Electrical Engineer, Power Dept., West Penn Power Co.; res., 5413 Stanton Ave., Pittsburgh, Pa.

*BRAFF, JOSEPH, Engineering Assistant, J. Livingston & Co., 70 East 45th St., New York, N. Y.

BRILL, ARTHUR T., Lieut., U. S. Navy Dept. of Electrical Engg. & Physics, U. S. Naval Academy, Annapolis, Md.

CROUCHLEY, FRANCIS D., Student, General Electric Co., 1030 W. Washington Blvd., Ft. Wayne, Ind.

DAGNALL, CLARENCE H., Instructor in Elec. Engg., Cornell University; res., 204 Fairmount Ave., Ithaca, N. Y.

*DIETZE, EGINHARD, Dept. of Development & Research, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

DIONNE, JOSEPH ALEXANDRE, Engineer (Electrical), Office of Supervisor of Plant, Bell Telephone Co., Montreal, P. Q.

DIXON, JOHN EDMUND, Commercial Engineer, General Electric Co., 1031 Monadnock Bldg., Chicago, Ill.

DUDREY, HOWARD E. A., Electrical Engineer, Union Gas & Electric Co., Cincinnati, Ohio.

*DUREN, GEORGE M., Division Inspector, American Tel. & Tel. Co., 823 Boatmen's Bank Bldg., St. Louis, Mo.

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*EVANS, DONALD G., Engineer, Wisconsin Gas & Electric Co., 410 Public Service Bldg., Kenosha, Wis.

FAY, LEON WARREN, Advertising Manager, Century Electric Co., 1827 Pine St., St. Louis, Mo.

FERNANDEZ, FERNANDO, First Substation Engineer, Lake Coleridge Power Plant, Addington Substation, Christchurch, N. Z.

*FISHER, J. CARL, Industrial Power Dept., Consolidated Gas & Electric Co., Baltimore, Md.

*FOWLER, WILLIAM KIRK, JR., Student Engineer, General Electric Co.; res., 26 Eagle Street, Schenectady, N. Y.

*FOX, HAROLD N., Electrical Engineer, Shepard Electric Crane & Hoist Co., Montour Falls, N. Y.

FRASER, CHARLES E., Electrical Inspector, U. S. Navy Dept., Navy Yard; res., 1203 Hancock St., Brooklyn, N. Y.

FUJITA, MORIO, Research Engineer, 4th Section of Electro-Technical Laboratory, Ministry of Communications, Tokyo, Japan.

*GANNETT, DANFORTH K., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

*GETTLIN, ALEX. A., Electrical Engineer, U. S. Cast Iron Pipe & Foundry Co., Burlington, N. J.; res., 2529 N. 30th St., Philadelphia, Pa.

GOODWIN, GEORGE L., Chief Electrician, Ludlow Mfg. Associates, Ludlow, Mass.

GRATWICKE, WALTER, British Aluminum Co., Ltd., 109 Queen Victoria St., London E. C. /4, England.

GRIGSBY, LOGAN C., Power Dept., United Railways Co. of St. Louis, 3869 Park Ave., St. Louis, Mo.

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*HANCOCK, MRYON S., Designer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 1013 Ross Ave., Wilkinsburg, Pa.

HEMENWAY, EVERETT G., Chief Electrician, Instructor in Gyro Compasses, Navy Electrical School, Hampton Roads, Va.

*HERSKOWITZ, LOUIS, Engineering Dept., Third Avenue Railway System; res., 247 W. 116th St., New York, N. Y.

*HINKLE, ALLEN ELLSWORTH, Designing Engineer, General Electric Co.; res., 68 Brown St., Pittsfield, Mass.

*HOTCHKISS, GROSVENOR, Engineer, Western Union Telegraph Co., 195 Broadway, New York; res., 146 Halsey St., Brooklyn, N. Y.

*HUTH, HERMAN R., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

HYDE, LOUIS H., Student Engineer, General Electric Co.; res., 1030 W. Washington Blvd., Ft. Wayne, Ind.
JAEGER, GEORGE A., JR., Electrician, United Electric Construction Co.; res., 507 West 158th St., New York, N. Y.
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*KELLY, JOYCE R., Electrical Engineer, Testing Laboratory, Western Electric Co., 463 West St., New York, N. Y.
*KENDALL, EDWARD N., Telephone Engineer, American Tel. & Tel. Co., 201 Telegraph Bldg., Harrisburg, Pa.
*KISO, DAIJIRO, Engineer, Industrial Division, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
KOIZUMI, MITSUO, Electrical Engineer, Anzan Steel Works, South Manchuria Railway Co., Dairen, Japan.
KONGSTED, LUDVIG P., Designing Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
LEA, EDWARD, Erecting Electrical Engineer, General Electric Co., Schenectady, N. Y.
LE BEAN, JOHN F., Draftsman, W. H. Taylor & Co.; res., 148 N. 7th St., Allentown, Pa.
LEE, ALEXANDER W. H., Operating Dept., N. Y. Edison Co., 208 W. 85th St., New York, N. Y.
LEUNG, NAI HANG, Assistant Electrical Engineer, West Penn. Power Company, Pittsburgh, Pa.; res., 64 Oxford St., Cambridge, Mass.
LOCKWOOD, JOSEPH B., Senior Operator, Lockport Light, Heat & Power Co., 32 Bacon St., Lockport, N. Y.
MACRAE, F. G., Electrical Engineer, Railway Improvement Co., 61 Broadway, New York, N. Y.
MALONE, JAMES JOSEPH, Supervising Engineer, Postmaster General's Dept., Melbourne, Australia.
MARLEY, GEORGE W., Instrument Tester, Commonwealth Edison Co.; res., 4010 Vincennes Ave., Chicago, Ill.
*MARSTELLER, GEORGE F., 440 Dayton St., Akron, Ohio.
MATTSON, CHARLES O., Electrician, W. & A. Fletcher Company; res., 400 Monroe St., Hoboken, N. J.
MATULICH, LAWRENCE C., Lyndock St., Hyde Park, South Australia, Aus.
MCKEAN, HAROLD S., Electrical Engineer, Canadian General Electric Co., 212 King St. W., Toronto, Ont.
MEADE, THOMAS R., Operator, Sub-station, Puget Sound Traction, Light & Power Company, 4545 California Ave., Seattle, Wash.
*MILLER, FRANK R., Student Engineer, General Electric Co.; res., 415 Brandywine Ave., Schenectady, N. Y.
MORLAN, SAMUEL E., Telephone Representative, Accounting Dept., Mountain States Tel. & Tel. Co., Denver, Colo.
MUNDY, SIDNEY G., Assistant Contract Engineer, Bruce Peebles & Co. Ltd., Edinburgh, Scotland.
MYERS, MORTIMER A., Electrical Engineer, The Maintenance Co.; res., 112 W. 103rd St., New York, N. Y.
NEWTON, ELMER G., Chief Steam & Electric Engineer, Pierce Oil Corp., Sand Springs, Okla.
*NORTON, JOSEPH E., Electrician & Trouble Man, Otis Elevator Co., Boston; res., 1190 Columbus Ave., Roxbury, Mass.
*OLSEN, OLAF M., Electrician, Baltimore & Ohio R. R., Washington, Ind.
*PENDARVIS, HARRY REED, Lieut. (j. g.), U. S. N., Chief Engineer, U. S. S. Porter, Navy Yard, Philadelphia, Pa.
*PETZING, ERWIN W., Telephone Engineering, Western Electric Co., Hawthorne; res., 939 N. Drake Ave., Chicago, Ill.
*PHILIPS, ROBERT C., Salesman, Canadian Westinghouse Co., Ltd., Bank of Hamilton Bldg., Toronto, Ont.
PINCKNEY, GLENN M., Designer, Frederick S. Holmes, 2 Rector St.; res., 481 W. 159th St., New York, N. Y.
POOLE, STAFFORD G., Shift Engineer, Municipal Electricity Works, Peterboro, Eng.
POULTERER, WILLIAM TAYLOR, Elec. Engineer, Electrical Dev. & Machine Co.; Philadelphia Electric Co. Supply Dept., 132 S. 11th St., Philadelphia, Pa.
RANDALL, LAURENCE C., Electrical Engineer, Brooklyn Rapid Transit Co.; res., 199 8th Avenue, Brooklyn, N. Y.
*REAGAN, MAURICE E., Inspector of Elec. Equipment, Kansas City Railways Co., 1500 Grand Ave., Kansas City, Mo.
RILEY, HUGH J., Chief Electrician, Printing Crafts Bldg., 461 8th Ave., New York, N. Y.
*ROBERTS, WALTER VAN BRAAM, Instructor, Princeton University, Princeton, N. J.
ROSENAUER, MOSES B., Instructor in Electrical Laboratory, Boston Trade School, Boston, Mass.
*RUKENBROD, J. K., Tester, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1308 Kirkpatrick Ave. N., Braddock, Pa.
*RUSSELL, MARSHALL H., Asst. Head, Train Control Test, General Electric Co., Schenectady, N. Y.
SHERMAN, HUGH S., Commercial Electrical Engineer, General Electric Co., St. Louis, Mo.
*SHETZLINE, ROY A., Telephone Engineering, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
*SHORT, PHILIP B., General Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
SINGER, SAMUEL B., Electrical Engineer, Century Electric Co.; res., 5174 Cabanne Ave., St. Louis, Mo.
SMITH, HIRAM G., Piedmont Power & Light Co., Burlington, N. C.
*SMITH, PAUL C., Oscillograph Operator, Test Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
SPARKS, RAYMOND E., Power Installer, Automatic Electric Co., Winnipeg, Man.
TALMAGE, CHARLES H., Manager, Western Electric Co., 41 W. Broadway, Salt Lake City, Utah.
*TASHIMA, YOSHIO, Asst. Switchboard Engineer, Westinghouse Elec. & Mfg. Co., Markham & Mangum Sts., Atlanta, Ga.
*TESSOHN, ISIDOR M., 948 Union Ave., New York, N. Y.
*THRALL, EDWIN F., Graduate Student, Sheffield Scientific School, Yale Univ., New Haven, Conn.; res., Plaza Hotel, New York, N. Y.
*TOWLE, NORMAN L., Elec. Engg. Dept., Iowa State College, Ames, Iowa.
UMPLEBY, GEORGE F., Elec. Engg. Dept., Consolidated Gas, Electric Light & Power Co., Baltimore, Md.
WARD, H. C., Sales Manager, General Electric Co., 1208 Granite Bldg., Rochester, N. Y.
*WEGMANN, CARL A., Electrician, Central Power Co.; res., 926 Rex Ave. N. E., Canton, Ohio.
WERDEN, EDWARD T., Draftsman, Interborough Rapid Transit Co., 98th St. & 3rd Ave., New York, N. Y.
*WHEELER, HERBERT H., Engineering Asst., Western Union Telegraph Co., 195 Broadway, New York, N. Y.
WHITNEY, ALLAN J., Charge Plant Dept., Whitney Company, 101 Park Ave., New York, N. Y.
WITTMAN, FRANCIS E., Sales Engineer, Canadian Westinghouse Co., 1207 Bank of Hamilton Bldg., Toronto, Ont.
WOOLSTON, LOUIS F. B., Electrical Engineer, General Electric Co., Pierce Bldg., St. Louis, Mo.
WRIGHT, ERNEST M., Electrical Engineer, Pacific Gas & Electric Co., 445 Sutter St., San Francisco, Cal.
ZUBE, HENRY EARNEST, Asst. to Chief Electrician, American Shipbuilding Co.; res., 1311 6th St., Lorain, Ohio.

Total 104

*Former enrolled student.

ASSOCIATES RE-ELECTED JANUARY 9, 1920

HUNT, RAYMOND, General Manager, Tide Water Power Company, Wilmington, N. C.
THERKELSEN, ERIC, Asst. Prof. of Mech. Engineering, Univ. of Montana; res., 716 S. Grand Ave., Bozeman, Mont.
VAN METER, R. H., Electrician, Union Carbide Company, Niagara Falls, N. Y.

MEMBERS ELECTED JANUARY 9, 1920

CREAGER, EDWIN F., Works Manager, Remy Electric Div., General Motor Corp., Anderson, Ind.
SEELY, GARRETT, T., Gen. Manager, Mahoning & Shenango Ry. & Lt. Co., Youngstown, Ohio.

FELLOW ELECTED JANUARY 9, 1920

Recommended for Election by the Board of Examiners, December 8, 1919

PEDERSEN, PEDER OLUF, Prof. of Elec. Engineering, The Royal Technical College, Copenhagen, Denmark.

Transferred to Grade of Fellow January 9, 1920

ALEXANDER, HARRY, Electrical and Mechanical Engineer, New York, N. Y.
ALEXANDERSON, E. F. W., Consulting Engineer, General Electric Co., Schenectady, N. Y.

Transferred to Grade of Member January 9, 1920

BURNHAM, ROY R., Consulting Engineer, Boston, Mass.
CORNEY, CHESTER A., Electrical Engineer, Stone & Webster, Boston, Mass.
DILLON, THEODORE H., Professor of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
HOWE, WILLIAM M., First Lieut., Corps of Engineers, U. S. Army, Washington, D. C.
NIKIFOROFF, BASIL, Electrical Engineer, Operating Dept., Alabama Power Co., Birmingham, Ala.
ROBISON, ARCH, Construction Supt., J. G. White Engineering Corp., Marcus Hook, Pa.
SCHMID, ERNEST E., Vice-President and Manager, Shield Electric Co., New York, N. Y.
WOOD, FRANK W., Vice-President and Chief Engineer, Chas. Cory & Son, Inc., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at meetings, held in November, 1919, and January, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

Recommended in November 12, 1919, to Grade of Member

JOHNSTON, A. LANGSTAFF, JR., Lieut. Comdr., U. S. N. R. F., Senior Asst. Inspector of Machinery, U. S. Navy, Newport News. Va.

Recommended in January 1920, to Grade of Fellow

GOLDSMITH, ALFRED N., Professor in Charge of Electrical Engineering, College of the City of New York, N. Y.

To Grade of Member

BEARDSLEY, CLIFFORD R., Electrical Engineer, Fred T. Ley & Co. Inc., Springfield, Mass.

CARROLL, RANDOLPH S., Superintendent, Underground Dept., Portland Railway, Light & Power Co., Portland, Ore.

DUBSKY, FRANCIS, Electrical Engineer, Transformer Engineering Dept., General Electric Co., Pittsfield, Mass.

FOSTER, BENJAMIN P., Electrical Engineer, E. I. Du Pont de Nemours & Co., Wilmington, Del.

HESTON, WALTER C., Industrial Power Engineer, Portland Railway, Light & Power Co., Portland, Ore.

HUNT, RAYMOND, General Manager, Tide Water Power Co., Wilmington, N. C.

LINCOLN, JAMES F., General Manager, Lincoln Electric Co., Cleveland, O.

MORTON, ROBERT B., Electrical Engineer, Toltz King & Day, St. Paul, Minn.

SCHIPPEL, HENRY F., Research Engineer, Ames Holden McCready, Ltd., Montreal, Que.

SOLOMON, NATHAN C., Contracting Electrical Engineer, New York, N. Y.

STRAW, JESSE B., Chief Engineer, The William Gordon Corp., Philadelphia, Pa.

WISEMAN, ROBERT J., Wire and Cable Engineer, National Conduit & Cable Co. Inc., Hastings-on-Hudson, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 28, 1920.

Adams, Claude H., Detroit, Michigan.
Adams, John R., (Member), Logan, West Virginia.
Adelberg, I. S., Cleveland, Ohio.
Admire, Amzi O., Cleveland, Ohio.
Ahearn, William H., Philadelphia, Pennsylvania.
Andrews, Joseph F., Atlanta, Georgia.
Appleman, Glen, Allentown, Pennsylvania.
Armstrong, Charles H., Atlanta, Georgia.
Armstrong, Vernon D., Seattle, Washington.
Austermiller, Elmer O., Steubenville, Ohio.
Bagby, C. C., Denver, Colorado.
Bain, James W., Montreal, Quebec.
Barnes, Shepard, Buffalo, New York.
Ballinger, John G., Toronto, Ontario.
Beach, Samuel W., Washington, D. C.
Beattie, William P., Norwood, Ohio.
Bechtol, Harvey W., (Member), Cleveland, Ohio.
Bendel, Emil H., San Luis Obispo, California.
Benzon, Axel, Curtis Bar, Maryland.
Bergegrun, Theo., Marion, Ohio.
Bird, Arthur A., Newark, New Jersey.
Biser, Mark H., Washington, D. C.
Blanding, Freeman A., Schenectady, New York.
Boice, William B., Toledo, Ohio.
Bowie, James W., Millbury, Massachusetts.
Bradfield, Joseph M., Atlanta, Georgia.
Bravo, Ricardo S., Jr., (Member), Sugarland, Texas.
Buelhausen, Edgar, Yonkers, New York.
Burgess, William H., Cleveland, Ohio.
Burrage, Claude, Milwaukee, Wis.
Burtzberger, Fred, New York, New York.
Byrd, Alfred A., Montreal, Quebec.
Caffrey, Charles S., Long Island City, New York.
Campbell, James S., Northbridge, Massachusetts.
Canada, William J., Boston, Massachusetts.
Carswell, Howard L., New York, New York.
Chen, Fountain C. Y., Schenectady, New York.
Chow, Nien-Tien, E. Pittsburgh, Pennsylvania.
Christian, William J., New York, New York.
Church, Oliver A., Boston, Massachusetts.
Clardy, Will J., E. Pittsburgh, Pennsylvania.
Clarke, Samuel A., Hamilton, Ont.
Clement, Luis F., (Member), Panama City, R. P.
Coldwell, Everett S., New York, New York.
Cook, Joel R., Cleveland, Ohio.
Cook, Percy E., Pittsburgh, Pennsylvania.
Cooper, Henry J., (Member), New London, Connecticut.
Costa, Jose de A., Philadelphia, Pennsylvania.
Crockett, Charles N., Kingsport, Texas.
Crofoot, Clarence E., Rochester, New York.
Crouch, Ernest L., Sharon, Pennsylvania.
Dale, Colin B., (Member), Cudahy, Wisconsin.
Dalzell, David R., Pittsfield, Mass.
Darland, Alvin F., Tacoma, Wash.
Daschke, Paul A., Jamaica, Long Island, New York.
Davenport, Frank B., (Member), Atlanta, Georgia.
Daza, Garbiel A., E. Pittsburgh, Pa.
Disque, Robert C., (Member), Philadelphia, Pa.
Dodge, Chester C., Schenectady, New York.
Dolph, Norman L., Detroit, Michigan.
Drake, Ralph A., Springfield, Mass.
Earle, Ralph H., Milwaukee, Wis.
Edquist, Paul E., Seattle, Washington.
Edwards, Lionel G., Healey Falls, Ontario.
Emrick, Alfred B., Detroit, Michigan.
English, Matthew R., Philadelphia, Pennsylvania.
Erickson, Robert W., (Member), Kearny, New Jersey.
Eschholz, Otto H., E. Pittsburgh, Pennsylvania.
Evans, Thomas McK., Ft. Wayne, Indiana.
Feldmann, Walther H., Baltimore, Maryland.
Fields, Bryant W., San Francisco, California.
Fields, Ernest, Cincinnati, Ohio.
Ford, Fred S., Wilmington, Delaware.
Forshee, Frank F., Flint, Michigan.
Frank, Theodore L., Omaha, Nebraska.
Franklin, Marcus R., Wilmington, Delaware.
Frohman, Oscar, Akron, Ohio.
Fuller, Stephen, J., New York, New York.
Fung, Willion Wai, E. Pittsburgh, Pennsylvania.
Furuki, Masumitsu, Schenectady, New York.
George, Everett E., (Member), Chicago, Illinois.
Gibaratz, George A., Wyandotte, Michigan.
Gilliatt, Charles F., Toronto, Ontario.
Gokhale, Dhankar L., (Member), Schenectady, New York.
Goldschmidt, Charles, (Member), Paris, France.
Gordon, Murray L., Ft. Wayne, Indiana.
Gotto, Anthony J., Ampere, New Jersey.
Gould, William S., Lowell, Massachusetts.
Gourdon, Paul E., New York, New York.
Grandy, Charles C., Fort Wayne, Indiana.
Green, James L., Regina, Saskatchewan, Canada.
Hagan, James S., E. Pittsburgh, Pennsylvania.
Hagar, George H., Vallejo, California.
Hales, Walter C., New York, New York.
Hammond, William P., (Member), Atlanta, Georgia.
Hathaway, Ernest C., Fall River, Massachusetts.
Hauser, Oscar E., Detroit, Michigan.
Hawker, Clifford F., Dayton, Ohio.
Hawkins, Crawford B., Birmingham, Alabama.
Hayashi, Ichiro, Schenectady, New York.
Heintzen, Harry R., Milwaukee, Wisconsin.
Heinzerling, Theodore W., Brooklyn, N. Y.
Helm, Carl H., St. Louis, Missouri.
Herman, John L., (Member), Portland, Maine.
Herod, William R., Schenectady, New York.
Herrick, Wilmer J., Baltimore, Maryland.
Hilton, Clarence E., Monarch, Wyoming.
Hinch, Edward F., Toronto, Ontario.
Ho, Molin, E. Pittsburgh, Pennsylvania.
Hoare, Stephen C., W. Lynn, Massachusetts.
Hoegen, Anna C., New York, New York.

Hoffman, A. J., Chicago, Illinois.
Hofgren, Axel A., Chicago, Illinois.
Hoke, Charles C., St. Louis, Missouri.
Holben, Wilmer P., South Orange, New Jersey.
Holden, Alfred R., Akron, Ohio.
Hollis, Victor D., Bluefield, West Virginia.
Holmes, Norris D., Uxbridge, Massachusetts.
Holton, Milton G., Minneapolis, Minnesota.
Hopkins, Warren B., (Member), Boston, Mass.
Hopper, Spencer D., Philadelphia, Pennsylvania.
Horner, Merritt, Jr., New York, New York.
Hubbard, Ralph B., Athens, Georgia.
Huckin, William J., Schenectady, New York.
Hugh, F. A., St. Louis, Missouri.
Hughes, Frank C., S. Boston, Massachusetts.
Hughes, James M., Schenectady, New York.
Hughes, Samuel B., Omaha, Nebraska.
Idelson, Michael N., Ampere, New Jersey.
Jalonack, Harold M., Schenectady, New York.
James, Bertram, (Member), Toronto, Ontario.
Jennings, Arthur G., Elmira, New York.
Jewell, Robert R., Dennison, Ohio.
Johnson, Clarence L., Hartford, Connecticut.
Johnson, Robert H., Chicago, Illinois.
Johnston, Austin L., Cincinnati, Ohio.
Kasparek, Frank P., Milwaukee, Wisconsin.
Kauffman, Harry M., Schenectady, New York.
Kellerman, Charles N., Hog Island, Pennsylvania.
Kennedy, Lyle W., Battle Creek, Michigan.
Kenney, Edward L., St. Louis, Missouri.
Kenward, Ernest, Toronto, Ontario.
Kietzman, Charles E., Milwaukee, Wisconsin.
Kilburn, Samuel G., Bluefield, West, Virginia.
Kilmer, William S., (Fellow), Washington, D. C.
Kinderman, William C., (Member), Stockton, California.
Knapp, Leland G., Chicago, Illinois.
Kodil, Charles E., Los Angeles, California.
Koehler, Glenn, New York, New York.
Koons, Gordon A., Carneys Point, New Jersey.
Kuehne, John H., Detroit, Michigan.
Kupshas, Alexander C., Chicago, Illinois.
Laing, George E., Toronto, Ontario.
Lebo, William F., Indianapolis, Ind.
Lofstrand, Arthur L., (Fellow) Port Angeles, Washington.
Long, Henry T., Charlotte, North Carolina.
Lovett, Israel H., Worcester, Mass.
Lowry, Ray S., Newton Falls, Ohio.
Loye, Donald P., New York, New York.
Lutz, Hobart F., Kansas City, Mo.
Mann, William C., St. Louis, Missouri.
Mansen, Theodore, R., Hog Island, Pennsylvania.
Maskey, Carle L., (Member), West Point, Virginia.
May, John T., Chicago, Illinois.
Merkel, Otto J., Ludlow, Mass.
Meyer, Carl A., Chicago, Illinois.
Meyer, Clarence C., Portland, Oregon.
Milburn, Loyal R., Cleveland, Ohio.
Mindt, Frederick E., Manchester, New Hampshire.
Moniesky, Nicholas, Schenectady, New York.
Moore, Harry H., Washington, D. C.
Moorhead, O. B., (Member), San Francisco, California.
Morgan, George R., Ithaca, New York.
Morroni, Anthony J., Washington, D. C.
Mullen, Clyde A., Coshocton, Ohio.
Mulvaine, Elmer A., Marion, Ohio.
Murray, William J., Elizabethport, New Jersey.
McCombs, Joseph H., Atlanta, Georgia.
McConnell, David F., Madison, Wisconsin.
Neahr, Will C., Denver, Colorado.
Norton, Paul T., Jr., Columbus, Ohio.
Nottorf, William E., Kansas City, Missouri.
O'Neil, William J., Springfield, Massachusetts.
O'Neill, Jerry B., Ashland, Wisconsin.
Osborn, Burr K., Ann Arbor, Michigan.
Owler, Duncan S., Fall River, Massachusetts.
Packer, Alfred H., Chicago, Illinois.
Packwood, George H., Jr., (Member), St. Louis, Missouri.
Painter, John C., Cincinnati, Ohio.
Palmison, Frank F., New York, New York.
Parker, Carleton, H., Seattle, Washington.
Patterson, Charles L., Boston, Massachusetts.
Peck, Warren O., Dunkirk, New York.
Peel, Edward R., Chicago, Illinois.
Pengelley, Walter G., Toronto, Ontario.
Penman, Roy F., Schenectady, New York.
Perry, Irving D., Newark, New Jersey.
Pfeil, Alfred L., Cleveland, Ohio.
Phelps, Walter A., Brooklyn, New York.
Philbrick, Frederick B., Cambridge, Massachusetts.
Playford, Everard W., Montreal, Quebec.
Poole, William E., New York, New York.
Porter, Arthur S., Hamilton, Ontario.
Pottinger, Clarence A., Milwaukee, Wisconsin.
Priess, William H., (Member), Boston, Massachusetts.
Purington, Ellison S., Washington, D. C.
Rader, Ray, Seattle, Washington.
Ramsey, John R., Long Island City, New York.
Rapp, Roy L., Pittsfield, Massachusetts.
Richardson, Frederick H., Pittsfield, Massachusetts.
Rider, Walter J., Binghamton, New York.
Ripley, Giles E., Fayetteville, Arkansas.
Robinson, Samuel M., (Member), San Francisco, California.
Rogers, Emerson B., Westboro, Massachusetts.
Roser, J. O. L., Pittsfield, Massachusetts.
Ryan, Francis J., Chicago, Illinois.
Salt, Lloyd B., Hyde Park, Massachusetts.
Sammis, Walter H., New York, New York.
Schluss, K., Tacoma, Washington.
Schorsch, Leopold, Long Island City, New York.
Schou, Rowland M., Lake Buntzen, British Columbia.
Scully, Robert T., Schenectady, New York.
Seiler, James F., Golden, Colorado.
Seybold, Lawrence F., Milwaukee, Wisconsin.
Seyforth, Otto K., Birmingham, Alabama.
Shipp, Carl B., Schenectady, New York.
Short, Frank A., Los Angeles, California.
Shoemaker, Maynard P., Washington, D. C.
Schreiber, Herbert, Elizabethport, New Jersey.
Simpson, William L., Chicago, Illinois.
Smith, A. L., Atlanta, Georgia.
Smith, Charles G., Medford Hillside, Massachusetts.
Smith, Charles L., Pittsfield, Massachusetts.
Smith, Frank P., New York, New York.
Smith, Hugh A., Boise, Idaho.
Sneed, William F., (Fellow), Toronto, Ontario.
Snyder, George R., Douglassville, Pennsylvania.
Spero, B. E., Cleveland, Ohio.
Spratt, Clarence W., St. Catharines, Ontario.
Stanford, Fred C., Ishpeming, Michigan.
Stern, Allan G., Philadelphia, Pennsylvania.
Stevenson, Alexander R., Schenectady, New York.
Stone, Selden E., Durham, N. C.
Suratt, L. P., Jr., Birmingham, Alabama.
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Thompson, Howard A., E. Pittsburgh, Pennsylvania.
Tillette, Hugh A., Pittsfield, Massachusetts.
Titcomb, Lee R., Newark, New Jersey.
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Turner, Hubert M., (Member), New Haven, Connecticut.
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Yamamoto, Kiyosho, New York, New York.
Yang, Tsao-Shing, Syracuse, New York.
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Adams, R. Dobson, Riccarton, New Zealand.
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Bundock, William A. W., Sydney, N. S. W., Australia.
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Dunderdale, Alston, Manchester, England.
Ghosh, Jagabandhu, Stratford, London, England.
Hacking, John, Buenos Aires, Argentine Republic.
Hangaard, F. B., Sydney, N. S. W., Australia.
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Lewthwaite, Fred A., Christchurch, New Zealand.
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Maxwell, Joseph H., Sydney, N. S. W., Australia.
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Narayanan, Manakal S. I. A., Pyinmana, Burma, India.
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Parkinson, George V., Havana, Cuba.
Perrin, Cecil M., (Member), Shanghai, China.
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Steortz, Charles M., Cristobal, Canal Zone.
Sriniaschari, V., Villupuram, Madras, India.
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Warner, Leslie T., Sydney, N. S. W., Australia.
Webber, George E. F., Buenos Aires, Argentine Republic.
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10929 Wulff, Harold A., University of California
10930 Brown, Bradley B., University of California
10931 Almquist, Milton L., University of California
10932 Roehrig, F. A., Oregon State College
10933 Merken, Jos. A., New York Electrical School
10934 Morgan, Harry R., Lafayette College
10935 Miller, Glenn B., Pennsylvania State College
10936 White, H. S., Worcester Polytechnic Institute
10937 Hill, A. W., Worcester Polytechnic Institute
10938 Folck, Wm. R., Kansas State Agricultural College
10939 Thomas, Alva A., Drexel Institute
10940 Peterson, C. F., Jr., Drexel Institute
10941 Davis, George G., Drexel Institute
10942 Hoernel, P. C., Brooklyn Polytechnic Institute
10943 Farmer, J. D., Rose Polytechnic Institute
10944 Chimene, Irvin E., Agricultural and Mechanical College of Texas
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10946 Goldston, L., Brooklyn Polytechnic Institute
10947 Russo, Julio, Delaware College
10948 Graham, Herschel A., University of Oklahoma
10949 Annappa, M. L., Union College
10950 Das, Bangalore H., Union College
10951 Naiman, Julius M., Armour Institute of Technology
10952 Malwitz, R. C., Armour Institute of Technology
10953 Miles, Russel, O., Armour Institute of Technology
10954 Knotek, Rudolph, Armour Institute of Technology
10955 Brown, R. W., Armour Institute of Technology
10956 Anderson, F. A., Armour Institute of Technology
10957 Dee, Jessica, George Washington University
10958 Little, James H., Delaware College
10959 Carpenter, Chas. B., State College of Washington
10960 Hsueh, Shao-Ch ng, Cornell University
10961 Griswold, D. W., Cornell University
10962 Cowsert, J. R., Cornell University
10963 Wright, Simeon M., Cornell University
10964 Simons, Mayrant, Cornell University
10965 Hogle, H. E., Jr., Cornell University
10966 Fiske, C. Stewart, Cornell University
10967 Liu, Jun-Sheng, Cornell University
10968 Carney, James C., Cornell University
10969 Reith, Marie, Cornell University
10970 Trostler, Hernea M., Cornell University
10971 West, Ralph G., Cornell University
10972 Simmen, Geo. P., Cornell University
10973 Kao, Hea, Cornell University
10974 Berg, Martin H., School of Engineering of Milwaukee
10975 Ragel, R., School of Engineering of Milwaukee
10976 Pettingill, C. E., School of Engineering of Milwaukee
10977 Poehler, B. C. C., School of Engineering of Milwaukee
10978 Potter, R., School of Engineering of Milwaukee
10979 Pugh, G. W., Jr., Georgia School of Technology
10980 Worley, Ivan H., University of Nebraska
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10985 Hearn, Wm. C., Alabama Polytechnic Institute
10986 Lasater, M. E., Alabama Polytechnic Institute
10987 Craven, Wm. M., Alabama Polytechnic Institute
10988 Dowling, A. M., Alabama Polytechnic Institute
10989 Allevato, W. J., School of Engineering of Milwaukee
10990 Arthurs, L. J., School of Engineering of Milwaukee
10991 Dopke, F. W., School of Engineering of Milwaukee
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10994 Stathas, P. P., School of Engineering of Milwaukee
10995 Budden, F. Wilfrid, University of Washington
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10999 Viele, Verne K., University of Nebraska
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11007 Liddle, Ralph W., University of Minnesota
11008 Hayward, L. W., University of Minnesota
11009 Briggs, Wm. G., University of Minnesota
11010 Sarisky, J. A., Ohio Northern University
11011 Jones, John W., Villanova College
11012 Isaacson, Charles B., Columbia College
11013 Bosway, Julius, Ohio State University
11014 Jenkins, Hartman E., Ohio State University
11015 Griffin, Spencer A., Ohio State University
11016 Hinderer, Otto G., Ohio State University
11017 Price, Karl D., Ohio State University
11018 Rei, Paul F., Ohio State University
11019 Teach, Francis A., Ohio State University
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Term expires July 31, 1923.
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The Last Stand of the Reciprocating Steam Engine

BY A. H. ARMSTRONG

Chairman Electrification Committee, General Electric Company

During the year 1920 the people of the United States will pay out for automobiles, not commercial trucks or farm tractors, but pleasure vehicles, a sum of money considerably greater than the estimated requirements of our steam railways for that year. The railways however, may find it very difficult and perhaps impossible to secure the large sums needed without government aid, notwithstanding the fact that the continued operation and expansion of our roads are of vital necessity to the welfare and prosperity of the country and all its industries. The will of the American public has always been constructive and undoubtedly, in due time, its voice will be heard and properly interpreted by its representatives in Washington with the resulting enactment of such laws as will permit our railways again to offer an attractive field for the investment of private capital.

The purpose of this paper is not to discuss the politics of the situation nor any necessary increase in freight rates that may be required to make our roads self-sustaining, but rather to offer certain suggestions as to the best manner of spending the sums that must ultimately be provided for new construction and replacements.

During the war period many lessons have been most clearly brought home to us and not the least of these is that there is something inherently wrong with our steam railroads. During the three generations of its development, we have become accustomed to look upon the steam engine as properly belonging to the railway picture and have given little thought to its wastefulness and limitations. It is around the steam locomotive that railway practise of today has gradually crystallized.

During the winter of 1917-18 our railways fell down badly when the need for them was the greatest in their history. It is true that the cold weather conditions were unprecedented and the volume of traffic abnormal but the weaknesses of the steam engine haulage were disclosed in a most startling and disastrous manner. Delayed passenger trains in cold weather can be endured by the traveling public in suffering silence or voluble expression, according to temperament; but the blocking of our tracks with frozen engines and trains, resulting in a serious reduction of tonnage in cold weather and a prohibitive delay in transportation of freight in times of great stress, is quite another thing and plainly indicates the inability of the steam engine to meet overloads and adverse climatic conditions.

In marked contrast to the adjourning steam engine divisions, the 440-mile electrified section of the Chicago, Milwaukee and St. Paul Railway continued to do business as usual all through that trying winter of 1917-18. The electric locomotives brought both freight and passenger trains over the electrified tracks in schedule time or better; in fact, it was quite customary to make up on the 440-mile electric run fully two hours of the time lost by passenger trains on adjoining steam engine divisions. While the results obtained upon the Chicago, Milwaukee & St. Paul were perhaps more spectacular due to the greater mileage electrically equipped, other electrified roads contributed similarly attractive records. The reliability and permanency of the comparison between steam and electric locomotive haulage is sufficiently guaranteed, therefore, by the results of several years' operation, to justify drawing certain conclusions regarding the merits of the two types of motive power. The following analysis of the railway situation is therefore offered for the purpose of exposing the fact that railroading today is in reality steam engine railroading and the general introduction of the electric locomotive will permit fundamental and far reaching changes being made in the method and cost of hauling freight and passenger trains.

The writer is not proposing the immediate electrification of all the railways in the United States, as many roads of lean tonnage would render no adequate return upon the large capital investment required, but is offering the following table of total operating statistics simply as a measure of the magnitude of the problem confronting us in the future. In this country it should be noted, however, that we have during the past thirty years installed electric power stations equal to twice the estimated capacity required for the electrical operation of every mile of our tracks today.

The tonnage passing over the tracks of our railways may be subdivided in a most interesting manner as shown in Table I.

TABLE I

TOTAL TON-MILE MOVEMENT

All Railways in United States—Year 1918

	Per cent	Ton miles
1—Miscellaneous freight cars and contents...	42.3	515,000,000,000
2—Revenue coal cars and contents..........	16.23	197,000,000,000
3—Locomotive revenue, driver weight only..	10.90	132,300,000,000
4—Passenger cars, all classes..............	16.13	196,000,000,000
Total revenue, freight and passenger...	85.56	1,040,300,000,000
5—Railway coal..........................	5.00	60,600,000,000
6—Tenders, all classes......................	6.50	78,800,000,000
7—Locomotive railway coal................	0.39	4,700,000,000
8—Locomotive, non-driving weight.........	2.55	31,000,000,000
Total non-revenue...................	14.44	175,100,000,000
GRAND TOTAL (All classes)......	100	1,215,400,000,000

The first four items, representing 85.56 per cent of the total ton-miles made during the year 1918, may be regarded as fundamentally common to both steam and electric operation. By introducing the electric loco-

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motive, however, the last four items are reduced to the extent of completely eliminating items (6) and (7), reducing item (5) by possibly 80 per cent and item (8) by one-half. Of the total of 14.64 per cent affected, therefore, it may be assumed for purposes of comparison that approximately 12 per cent or 146,000,000,000,ton-miles at present hauled by steam engines over our roads will be totally eliminated with electric locomotive haulage. This ton-mileage eliminated is equal to over 20 per cent of items (1) and (2) representing the revenue producing freight traffic on our railways. In other words, if all our railways were completely electrified they could carry one-fifth more revenue producing freight tonnage with no change in present operating expenses or track congestion.

It is evident that the greater part of the tonnage reduction effected by electrification is included in items (5) and (6), representing the railway coal movement in cars and engine tenders. The steam engine tender will of course entirely disappear, while the railway coal haulage will be largely curtailed by utilization of water as a source of power and the establishment of steam power houses as near coal mines as an abundant supply of good condensing water and load demand will permit. While the water power should be utilized to the fullest economical extent, the greater portion of the railway power must undoubtedly be supplied by coal, due to the unequal geographical distribution of water power available.

Even with coal as a source of power, it may not be fully appreciated just how enormous is the saving made by burning fuel in large modern power stations under the most efficient conditions possible, instead of under the boilers of 63,000 engines which by necessity must be designed and operated for service rather than for fuel economy. During the year 1918 the fuel used by the railways is reported to be shown in Table II.

TABLE II

RAILWAY FUEL 1918

Total coal production (all grades)	678,211,000 tons
Used by steam railways	163,000,000 tons
Percentage of total	24 per cent
Total oil marketed in U. S.	355,927,000 bbl.
Used by steam railways	45,700,000 bbl.
Percentage of total	5.8 per cent
Coal equivalent of oil at 3½ bbl.	13,000,000 tons
Total equivalent railway coal	176,000,000 tons

A quarter of all the coal mined in the United States is consumed on our railways and the following analysis will point out some features of this extreme wastefulness which are inseparable from steam engine operation.

During the year 1910, exhaustive tests were made upon the Rocky Mountain Division of the C., M. & St. P. Ry. to determine the relation existing between the horse power hours work done in moving trains and the coal and water consumed on the steam engines in service. Table III gives the results of these tests:

TABLE III

C., M. & ST. P. RY.; ROCKY MOUNTAIN DIVISION

Coal and Water Used

	Water per h.p-hr.	Water per lb. coal	Coal per h.p-hr.
Three Forks-Piedmont	39.6	5.08	7.75
Piedmont-Donald	35.4	4.70	7.54
Deer Lodge-Butte	39.7	4.85	8.31
Butte-Donald	40.4	4.86	8.74
Harlowton-Jenny	38.0	4.09	8.90
Jenny-Summit	44.2	4.65	9.48
Three Forks-Piedmont	41.4	6.51	6.37
Piedmont-Donald	40.2	5.63	5.78
Average of eight tests	39.86	5.04	7.86

The records were obtained during the portion of the runs that engines were doing useful work in overcoming train and grade resistance, that is, all standby losses were excluded. The through run, however, included such losses in the magnitude shown in Table IV:

TABLE IV

STANDBY LOSSES

	Coal per hour
Fire banked in roundhouse	150 lb.
Cleaning fires for starting	800 lb.
Coasting down grade	950 lb.
Standing on passing track	500 lb.

Adding standby losses to the average of 7.86 lb. per horse power hour obtained in the preceding eight tests the total actual coal consumed under the engine boiler in twenty-four hours divided by the actual work performed by the engine is found to be 10.18 lb. per horse power hour at the driver rims.

As the result of this particular series of tests it was determined that the coal consumed while doing useful work was raised 30 per cent by standby losses. It should be appreciated in this connection moreover that this value was obtained on through runs with no yard switching service or adverse climatic conditions. It may be concluded therefore that under all conditions of service fully one-third of the coal burned on our steam engines today is absolutely wasted in standby losses of the general nature indicated above.

Supplementing these tests, a 30-day record was kept of all the coal used on the entire Rocky Mountain Division and the total engine, tender, and train movement reduced to horse power hours, resulting in a value of 10.53 lb. coal consumed per horse power hour at the driver rims. Both of the above values were based upon constants of 6 lb. per ton train resistance at all speeds and 0.7 lb. per ton per degree of curvature as determined in part by dynamometer car tests and representative of general railway operation. Reducing the average coal values of the test runs and the 30-day record per

horse power hour to electrical constants, we arrive at the data shown in Table V:

TABLE V

COAL EQUIVALENT PER KW-HR.; STEAM OPERATION

Coal per h.p.-hr. at driver rims	10.27 lb.
Coal per kw-hr. at driver rims	13.75 lb.
Coal per kw-hr. at power supply on basis 55 per cent efficiency	7.56 lb.

It is this last figure of 7.56 lb. of coal burned on steam engines to get the equivalent tonnage movement of one kilowatt-hour delivered from an electric power station that is of special interest to this discussion. Comparing coal and electrical records on the Butte, Anaconda & Pacific Railway before and after electrification results in arriving at the value of 7.17 lb. of coal previously burned on the steam engines to equal the same service now performed by one kilowatt-hour input at the substations, a figure comparing favorably with 7.56 lb. above arrived at by an entirely different method.

TABLE VI

ANALYSIS OF ROUNDUP COAL USED

Fixed carbon	49.26 per cent
Volatile carbon	38.12 per cent
Ash	7.74 per cent
Moisture	4.88 per cent
B.t.u.	11899

Making the due allowance for the fact that roundup coal is somewhat low in heat units, it is nevertheless within the limits of reasonable accuracy to assume that the steam engines operating over all our railways are consuming coal at a rate closely approximating 12.75 lb. per kilowatt-hour of useful work done, as measured at the driver rims or 7 lb. per kilowatt-hour as measured at a power station and including for convenience of comparison the transmission and conversion losses inherent to electrical operation.

An electric kilowatt can be produced for so much less than 7 lb. of coal that we are now in position to finally forecast the approximate extent of the coal economy that would result from electrification.

TABLE VII

RELATION BETWEEN KW-HR. AND TON-MILES CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

Avery-Harlowton

Year 1918

	passenger	freight
Average weight locomotive	300 ton	284 ton
Locomotive miles, 1918	651,000	1,431,500
Locomotive ton-miles	195,000,000	407,000,000
Trailing ton-miles	434,406,000	2,903,099,000
Total ton-miles	629,406,000	3,310,049,000
Kilowatt-hours	24,890,000	105,287,000
Watthours per ton-mile	39.6	31.9
Ratio Locomotive to Total	31 per cent	12.3 per cent
Watthours per ton-mile combined movement	33.2	
Ratio locomotive to total combined movement	15.25 per cent	

All power values in Table VII are given at the point of supply from the Montana Power Company at 100,000 volts and include deductions made for the return of power due to regenerative braking of the electric locomotives on down grades, amounting to approximately 14 per cent of the total. Owing to the excessive rise and fall of the profile of the electrified zone of the C., M. & St. P. Ry., its operation is materially benefited by regenerative electric braking and the value of 33.2 watthours per ton mile for combined and passenger movement should possibly be raised to the round figure of 40 to make it apply more nearly to conditions universally obtaining on more regular profiles.

Hence referring again to the ton-mile values of Table I:

Total ton-miles, 1918	1,215,400,000,000
Watthours ton mile	40
Kw-hr. total movement	48,700,000,000
Coal required at 7 lb. per kw-hr.	170,000,000 ton

The actual equivalent coal consumed on our steam railways for the year 1918 is given as 176,000,000 tons, closely approximating the figure of 170,000,000 tons estimated above from the operating results obtained on the C., M. & St. P. electrified zone. These several values check so closely as to justify the completion of the fuel analysis of the railways as shown in Table VIII:

TABLE VIII

COAL SAVING BY ELECTRIFICATION

Total ton-miles steam	1,215,400,000,000
Reduction by electrification	146,000,000,000
Total ton-miles electric	1,069,400,000,000
Kw-hr. electric at 40 watts	42,776,000,000
Coal on basis 2½ lb. per kw-hr.	53,500,000 tons
Equivalent railway coal 1918	176,000,000 tons
Saving by electrification	122,500,000 tons

The startling conclusion arrived at is that approximately 122,500,000 tons of coal, or more than two thirds the coal now burned in our 63,000 steam engines, would have been saved during the year 1918 had the railways of United States been completely electrified along lines fully tried out and proved successful today. This vast amount of coal is 50 per cent greater than the pre-war exports of England, and twice the total amount consumed in France for all its railways and industries. Moreover, the estimate is probably too conservative as no allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities.

Perhaps no nation can be justly criticized for lavishly using the natural resources with which it may be abundantly provided. In striking contrast with the picture of fuel waste on the railways in this country however is the situation presented in Europe at this writing.

Faced with a staggering war debt, with two millions of its best men gone and an undetermined number incapacitated for hard labor, and with so much reconstruction work to do, France has to contend also with the destruction of half its coal producing capacity. Before the war, France imported twenty-three million of

the sixty-five million tons of coal consumed. It is estimated that the full restoration of coal mines in the Lens region will take ten years to accomplish, which means materially increasing the coal imported into France if pre-war consumption is to be reached, as the relief rendered from the Saar District will not compensate for the loss on productivity of the mines destroyed by the Germans. This situation is being promptly met in part by France in the appointment of a Commission to study the feasibility of the general electrification of all its railways with special reference to immediate construction in districts adjacent to its three large water-power groups, the Alps, the Pyrenes, and the Dordoyne or Central plateau region. It is proposed to electrify 5200 miles of its total of 26,000 miles of railways during a period covering twenty years. If this work is accomplished at a uniform rate of 260 miles a year, it is a most modest program considering the extreme necessity for the improvement.

In even worse plight is Italy with practically no coal of its own and compelled to import its total supply of 9,000,000 tons. The war has brought home to these countries what it means to be dependent upon imported fuel for their very existence and both Italy and Switzerland are also proceeding with extensive plans for railway electrification. Contrary to the general understanding, the mines of Belgium are not destroyed, but the need of fuel economy is very acute and this country also has broad plans for railway electrification with immediate construction in view.

Recognizing the many advantages of electric operation of its railways, Europe furthermore considers this a most opportune time to start the change rather than to spend its limited funds in replacing worn out and obsolete steam equipment in kind. Also in marked contrast to the American attitude is the sympathetic interest and constructive assistance rendered by the Governments abroad in regard to the vital matter of rehabilitation of its railway systems. It would not be without precedent if the next decade witnessed England and the Continent outstripping this country in the exploitation of another industry which, while possibly not conceived here, has certainly been more fully developed and perfected in America than elsewhere.

From figures given, the conclusions in Table IX are arrived at in the matter of power station capacity required for complete electrification of the railways in the United States.

TABLE IX

RAILWAY POWER REQUIRED

Kw-hr. electric operation, 1918	42,776,000,000 kw-hr.
Average load, 100 per cent load-factor	4,875,000 kw.
Power station capacity at 50 per cent load-factor	9,750,000 kw.

It appears therefore that approximately 10,000,000 kw. power station capacity would have been sufficient to run all the railroads for the year 1918, or one-half the station capacity which has been constructed during the past thirty years.

TABLE X

ESTIMATED POWER STATION CAPACITY UNITED STATES YEAR 1918

Central stations	9,000,000 kw.
Electric railways	3,000,000 kw.
Isolated plants	8,000,000 kw.
Total	20,000,000 kw.

In the order of magnitude, therefore, it is not such a formidable problem to consider the matter of power supply for our electrified railways and it becomes evident also that the railway power demand will be secondary to industrial and miscellaneous requirements.

Such being the case, the question of frequency of electric power supply becomes of great importance, if the full benefit is to be obtained from extensive interconnected generating and transmission systems covering the entire country. Indeed with the full development of interconnected power systems supplying both railway and industrial load from the same transmission wires, the above assumption of 50 per cent load-factor for the railway load can be materially bettered.

In this connection a method of limiting the troublesome peak load hitherto considered inherent to railway power supply has been in successful operation on the electrified C., M. & St. P. zone for the past year. With unrestrained peaks, the load-factor was approximately 40 per cent, but this low value has been raised to nearly 60 per cent by the installation of an inexpensive and most satisfactory device known as the power limiting and indicating apparatus.

TABLE XI

LOAD-FACTOR RECORDS C., M. & ST. P. RY.

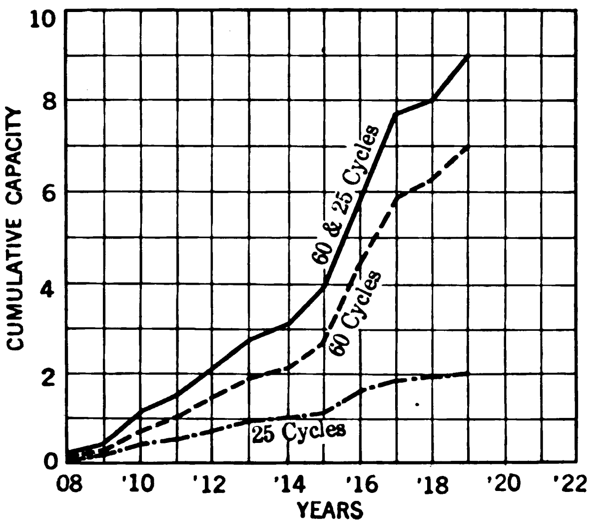
1919

	Per cent duration of peak	Per cent load-factor
April	6.4	59.3
May	4.6	56.1
June	1.6	56.5
July	0.7	55.6
August	9.5	58.8
September	4.1	54.7

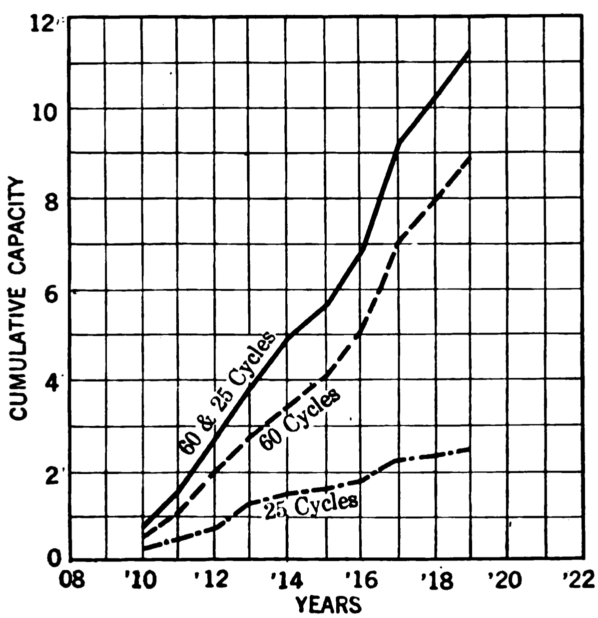
The readings of Table XI cover the performance on the 220 miles of the Rocky Mountain Division supplied by seven substations controlled as a unit. A load-factor of nearly 60 per cent brings the electric railway within the list of desirable customers and makes it possible for power companies to quote attractively low rates for power.

Returning again to the question of power supply, it is instructive to note the general trend toward a higher frequency as evidenced by the turbine and transformer sales of the General Electric Company during the past decade.

It is quite evident that 60 cycles is rapidly becoming the standard frequency in America; and many instances are on record where it has replaced lower frequencies, principally 25 cycles. This fact in no manner handicaps the future development of electric railways, as entirely satisfactory power can be obtained from 60-cycle transmission lines through synchronous converters or synchronous motor-generator sets, depending upon the



Comparative Sales of 60 and 25-Cycle Turbines



Comparative Sales of 60 and 25-Cycle Transformers

Fig. 1

direct-current trolley voltage desired. Indeed a growing appreciation of the declining importance of 25-cycle power generation in this country contributed largely to the demise of the single-phase system, as its chief claim for recognition is wiped out with the introduction of the motor-generator substations required with 60-cycle supply.

While America apparently has adopted 60 cycles as its standard frequency and can look forward to unlimited interconnection of its large power systems, European practise is evidently crystalizing on 50 cycles. The situation abroad is as yet, however, not clearly defined. In such a small compact country as Switzerland for instance, where so much electrical development is taking place, there is much conflict of frequencies. Apparently there is little appreciation of the advantages resulting from interconnected power stations; in fact the Loetschberg Railway is supplied with power from 15-cycle waterwheel-driven generators placed in the same power station with 42-cycle units supplying industrial load while in the same immediate district there is a 50-cycle transmission line and no tie-in frequency changer sets as yet installed to interconnect any two frequencies. The power company, power consumer and electrical manufacturer pay heavily for the complication imposed by maintaining three frequencies where only one is needed, and growing appreciation of this fact may lead to the standardization of 50 cycles in Switzerland and thus swing that country in line with its neighbors and ultimately bring about a more economical ratio of installed generator capacity to average load demand for the country as a whole.

A good example of the necessity for improvement in power distribution conditions in Switzerland is provided in the supply of power to the Loetschberg Railway as illustrated in Table XII.

TABLE XII

POWER SUPPLY TO THE LOETSCHBERG RAILWAY

March, 1919

Total for month	540,180 kw-hr.
Average of six 15-min. peaks	3,489 kw.
Load-factor, basis 24 hours	20.8 per cent

As the railway was operating for only seventeen hours per day, the load-factor during actual operation is somewhat better than 20.8 per cent. On the other hand, the actual momentary peak load greatly exceeded 3489 kw.; and this very fluctuating railway load furnishes a good illustration of the need of combining it with other diversified loads, in order to keep down the fixed investment of power station equipment now set aside for this isolated railway load. For example, the 60 per cent load-factor of the C., M. & St. P. power demand is the ratio of average to momentary peak while the Loetschberg Railway peak load is determined by six 15-min. peaks with momentary peaks greatly in excess of this figure.

Apparently the adoption of a standard frequency of 50 cycles would meet all general requirements in Switzerland, but would necessitate the installation of frequency-changing substations to meet the demands for 15-cycle, single-phase railway power. If the electrified railways are to be benefited therefore from the establishment of a common generating and transmission system in Switzerland, the choice of the single-phase railway system might possibly be considered unfortunate, viewed in the light of modern development in

power economics and the successful adaptation of the less expensive and more flexible direct-current motor to high trolley voltages.

From the power station standpoint, the electrification of our railways admits but one conclusion. We have some 63,000 engines now in operation and their average combined load amounts to approximately four million horse power at the driver rims or only an insignificant total of 65 h.p. for each engine owned. It is true that, owing to the shopping and to one cause or another, a large proportion of these engines are not in active service at all times, still the average twenty-four hour output of each engine is less than 10 per cent of its rating. In the case of the C., M. & St. P. electrification the average load of each individual electric locomotive is only 15 per cent of its continuous rating, but by supplying power to 45 electric locomotives from one transmission system, the average combined load-factor is raised to nearly 60 per cent, a figure which could even be surpassed on roads of more regular profile. Furthermore when the railway load is merged with the lighting and industrial power of the district and the whole diversified load supplied from the same 60-cycle transmission and generating system, it is quite evident that all conditions are most favorable for the efficient production of power. In this country such an achievement will probably be governed by the laws of economic return upon the capital required because our vast natural fuel resources are properly regarded as inexhaustable, but in Europe there is the compelling spur of stern necessity behind the movement to utilize economically the water powers they possess in place of the coal they cannot get.

Fig. 2—Twin Views Central Terminal—"Before and After"

While the much discussed subject of power generation and transmission is a very vital part of the railway electrification project, chief interest centers in the electric locomotive itself. Few realize what a truly wonderful development has taken place in this connection in a comparatively few years and how peculiarly fitted this type of motive power is to meet the requirements of rail transportation. Free from the limitations of the steam boiler, and possessing in the electric motor the most efficient and flexible known means of transmitting power to the driving axles, the electric locomotive gives promise of revolutionizing present steam railway practise when its capabilities become fully recognized. The only limits placed upon the speed and hauling capacity of a single locomotive are those imposed by track alignment and standard draft rigging. Only questions of cost and expediency control the size of the locomotive that can be built and operated by one man, as there are no mechanical or electric limitations that have not been brushed aside by careful development. Just what this means in advancing the art of railroading is as yet but faintly grasped, no more than the boldest prophet of twenty years ago could have fully pictured the change that has taken place at the Grand Central Terminal as the result of replacing steam by electricity.

Progress in utilizing the capabilities of the electric locomotive have been slow. It is hard to break away from life-long railway traditions established by costly experience in many cases. In consequence the electric locomotive has thus far simply replaced the steam engine in nearly similar operation. Even under such conditions of only partial fulfillment of its possibilities the electric locomotive has scored such a signal operating success as to justify giving it the fullest consideration in future railway improvement plans.

On the C., M. & St. P. Ry. 42 electric locomotives have replaced 112 steam engines and are hauling a greater tonnage with reserve capacity for still more. On this and other roads, electrification has set a new standard for reliability and low cost of operation. In fact, although no official figures have yet been published, it is an open secret that the reductions in previous steam operating expenses on the C., M. & St. P. Ry. are sufficient to show an attractive return upon the twelve and a half millions expended for the 440 miles of electrification, without deducting the value of the 112 steam engines released for service elsewhere. As the

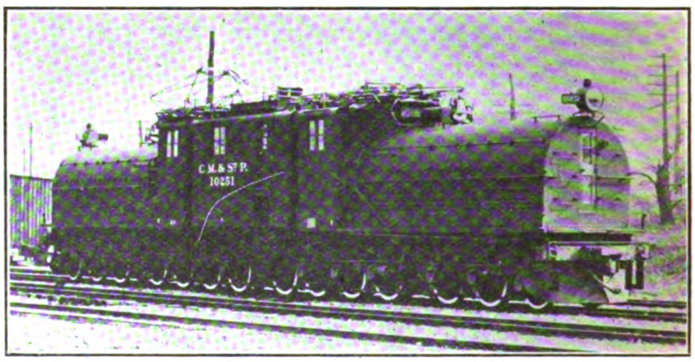


Fig. 3—Chicago, Milwaukee and St. Paul Gearless Locomotive

electric locomotive is destined to leave its deep impression upon the development history of our railways, it is fitting that the remainder of this paper should be devoted to its consideration.

Our steam engine construction is unsymmetrical in wheel arrangement, must run single ended, and is further handicapped with the addition of a tender to carry its fuel and water supply. The result has been much congestion at terminals; and the necessary roundhouses, always with the inevitable turn tables,

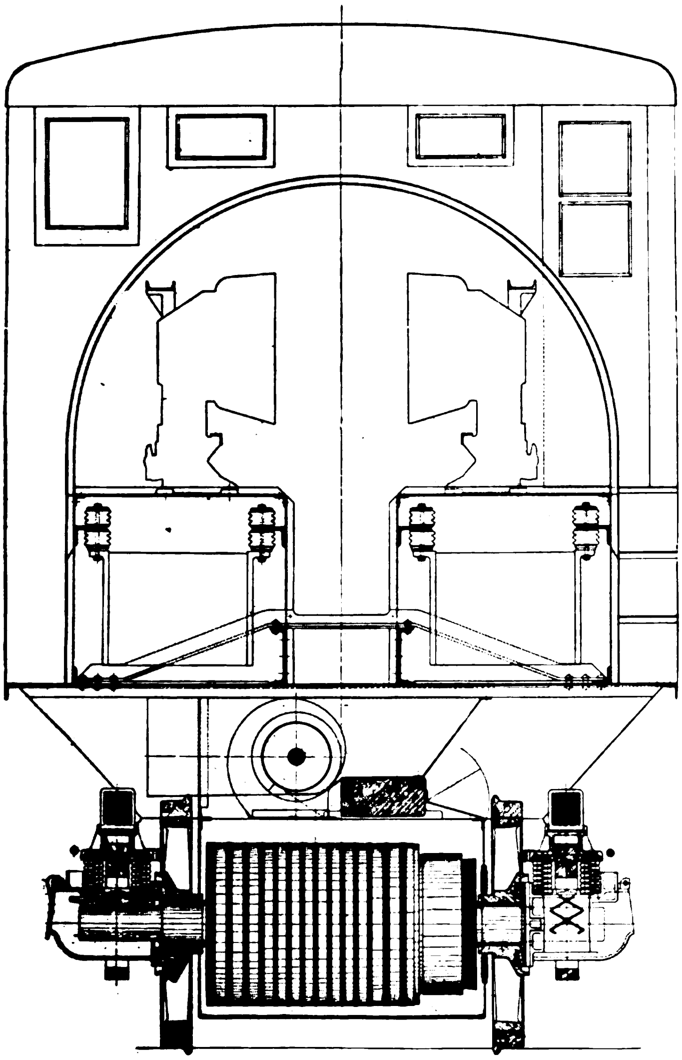


Fig. 4—End Elevation Showing Motor-Line Drawing—C., M. & St. P. Gearless Locomotive

ash pits, and coal and water facilities, have occupied much valuable land; and in addition steam operation has greatly depreciated the value of neighboring real estate. The contrast offered by the two large electric terminals in New York City is too apparent to need more than passing comment, and similar results may be expected on the fulfillment of plans for electrifying the Chicago terminals.

While it has been a simple matter to design electric locomotives to run double ended at the moderate speed required in freight service, the problem of higher speed attainment, exceeding 60 miles an hour, has presented greater difficulties. The electric motor is however so adaptable to the needs of running gear design that electric locomotives are now in operation which can meet all the requirements of high-speed passenger-train running. These results, also, are obtained with less than 40,000 lb. total weight, and 9500 lb. non-spring borne or "dead" weight on each driving axle, and finally, but not least, with both front and rear trucks riding equally well, a success never before achieved in locomotives of such large capacity.

In connection with the riding qualities of electric locomotives, it is of interest to note the conclusions that the Committee of the American Railway Engineering Association, F. E. Turneaure, Chairman, reached in their report of 1917.

From the results of the tests on the electrified section of the Chicago, Milwaukee & St. Paul Railway, the tests made in 1916 on the Norfolk and Western, and the few tests made in 1909 at Schenectady, N. Y., it would appear to be fairly well established that the impact effect from electric locomotives is very much less than from steam locomotives of the usual type. Comparing

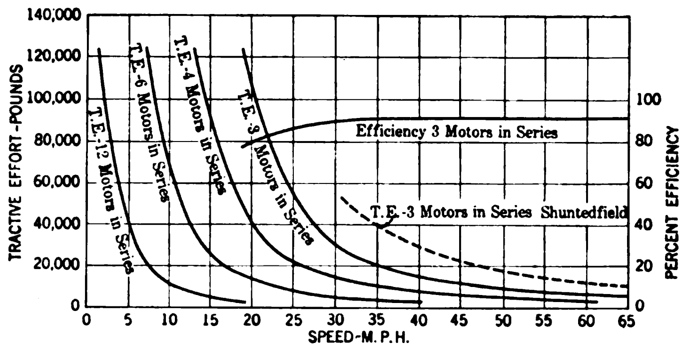


Fig. 5—Characteristic Curves 3000-Volt D-C. Gearless-Motor Locomotive—For C., M. & St. P. R. R.

results obtained in these tests with the results from steam locomotives, it would appear that the impact from electric locomotives on structures exceeding, say, 25 ft. span length, is not more than one-third of the impact produced by steam locomotives.

There is as yet no general acceptance of a standard design of electric locomotive. Geared side-rod construction for heavy freight service and twin motors geared to a quill for passenger locomotives appear to find favor with the Westinghouse-Baldwin engineers, while the General Electric Company goes in for the simple arrangement of geared axle motor for freight and gearless motors for passenger locomotives. In both Switzerland and Italy the side-rod locomotive enjoys an almost exclusive field. How much of this preference for side-rod construction is due to the restrictions imposed by the use of alternating-current motors is hard to determine, but the facts available indicate both in this country and abroad the uniformly higher cost of repairs of this more complicated form of mechanical drive.

The electric railway situation in Italy is further complicated by the employment of three-phase induction motors with all the attendant handicaps of double

overhead trolleys, low power-factor, constant speeds, and overheating of motors resulting from operation on ruling gradients with motors in cascade connection. In many respects the non-flexible three-phase induction motor is poorly adapted to meet the varied requirements of universal electrification; and in consequence Italian engineers are still struggling with the vexing question of a system, which may however be in a fair way of settlement through the adoption of a standard of 50 cycles as the frequency of a nation-wide interconnected power supply, thus throwing the preponderance of advantages to high-voltage direct current.

The extreme simplicity of the gearless motor locomotive appeals to many as does its enviable record of low maintenance cost, reliability, and high operating efficiency, as exemplified by its unvarying performance in the electrified zone of the New York Central for the

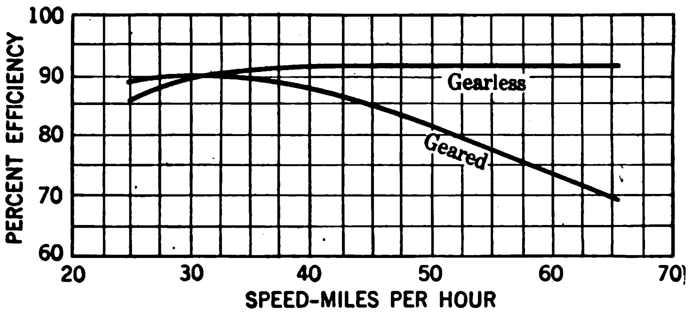


FIG. 6—EFFICIENCY CURVES PRESENT GEARED AND NEW GEARLESS C., M. & ST. P. LOCOMOTIVES

past twelve years. Table XIII shows that the high cost of living did not appear to have reached this favored type of locomotive until the year 1918.

TABLE XIII
MAINTENANCE COSTS NEW YORK CENTRAL

	1913	1914	1915	1916	1917	1918
Number locomotives owned	48	62	63	63	73	73
Average weight, tons	118	118	118	118	118	118
Cost repairs per locomotive mile	4.32	4.03	4.45	3.78	4.01	6.26

The records on the C., M. & St. P. locomotive are equally remarkable when considering their greater weight and the more severe character of service.

TABLE XIV
LOCOMOTIVE MAINTENANCE COSTS CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

	1916	1917	1918
Number locomotives owned	20	44	45
Average weight, tons	290	290	290
Cost repairs per locomotive mile	8.21	9.62	10.87

In both these instances the cost of repairs approaches closely to three cents per 100 tons of locomotive weight. Giving due credit to the excellent repair shop service rendered in each case, it is instructive to note that three cents per 100 tons maintenance cost of these direct-current locomotives is less than half the figures given for any of the alternating-current locomotives operating in the United States or in Europe.

Compared with the cost of repairs for equivalent steam engines, the above figures for electric locomotives are so very favorable as to justify the general statement that electric motive power can be maintained for approximately one-third of the cost of that of steam

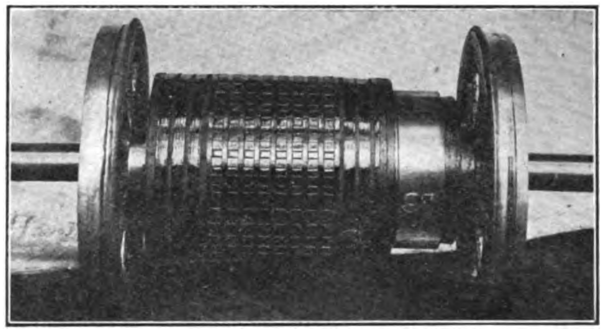


FIG. 7—GEARLESS ARMATURE AND WHEELS

engines for the same train tonnage handled. As locomotive maintainance is a measure of reliability in service and in a way expresses the number of engine failures, it is quite in keeping with the records available to state also that the electric locomotive has introduced a new standard of reliability that effects material savings in engine and train crew expense as well.

While the first cost of electrification is admittedly high, it may in certain instances be the cheapest way to increase the tonnage carrying capacity of a single

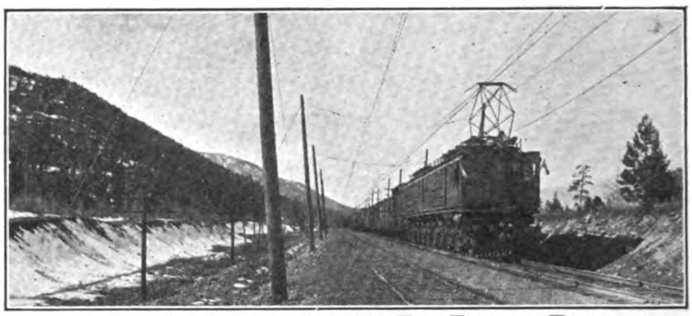


FIG. 8—C., M. & ST. P. 5000-TON FREIGHT TRAIN

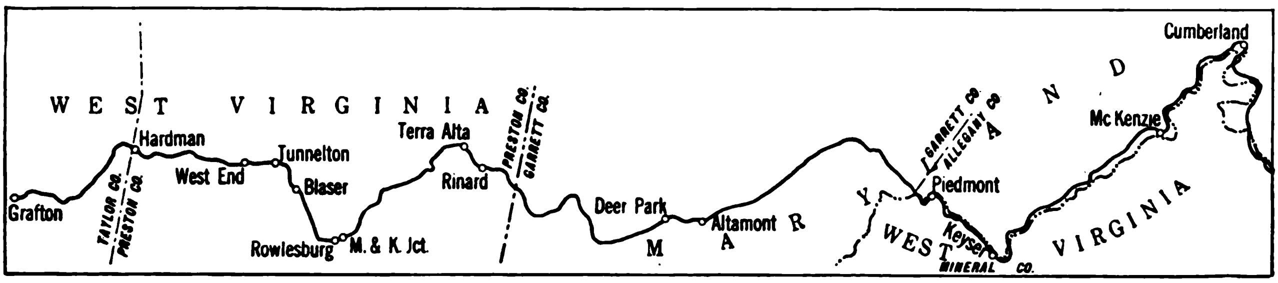
track especially in mountain districts where construction is most expensive and steam engine operation is most severely handicapped. In this connection a comparison of steam and electric operation on the C., M. & St. P. Ry. may be summarized as follows:

For the same freight tonnage handled over the Rocky Mountain Division, electric operation has effected a reduction of 22½ per cent in the number of trains, 24.5 per cent in the average time per train, and has improved the operating conditions so that nearly 30 per cent more tonnage can be handled by

electric operation in about 80 per cent of the time it formerly took to handle the lesser tonnage by steam engines. This means a material increase in capacity of this single-track line which may be conservatively estimated in the order of at least 50 per cent and probably more. In other words, on this particular road, electrification has effected economies which sufficiently justify the capital expenditure incurred and furthermore has postponed for an indefinite period any necessity for constructing a second track through this difficult mountainous country.

Further instances could be cited where the benefits of electrification are badly needed and many of these are fails to respond to our advancing needs. Electrification affords a cheaper and better means of securing increased track capacity and improved service than by laying more rails and continuing the operation of still more steam engines in the same old wasteful way.

To conclude the startling picture of our present railway in efficiency, we are today wasting enough fuel on our steam engines to pay interest charges on the cost of completely electrifying all the railways in the United States, fuel that Europe stands in sad need of and which England and Germany, the pre-war coal exporting countries, cannot now supply. With operating expenses mounting to 82 per cent of revenue, inadequate



B. & O. R. R.—Cumberland Division
Cumberland to Grafton

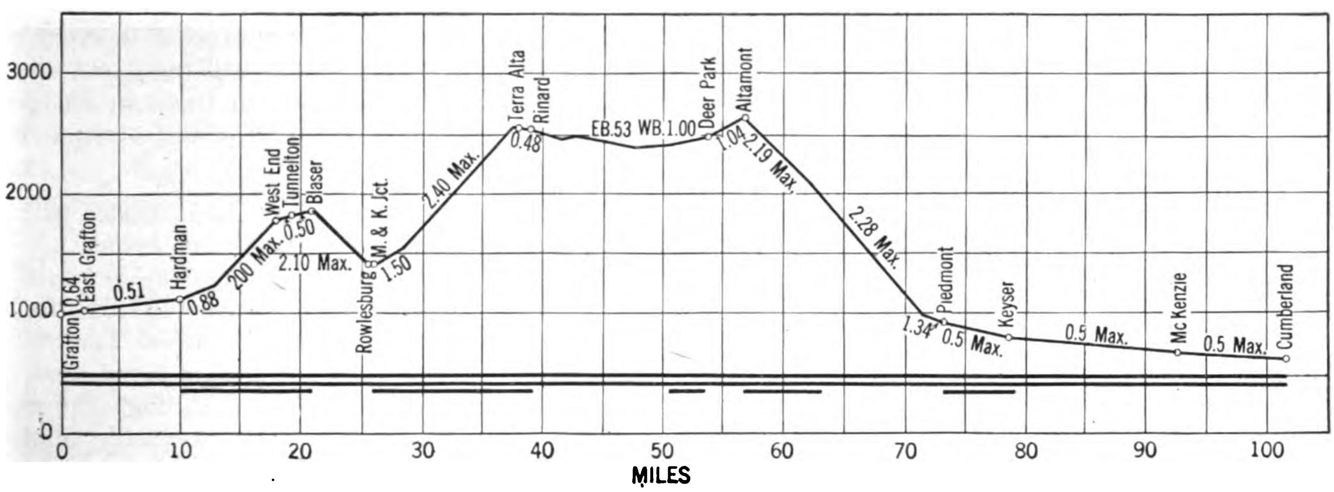


Fig. 9
West End Cumberland Division—Baltimore & Ohio Railroad
Condensed Profile—Showing Ruling Grades

coal-carrying roads, among which the Virginian Railway stands out conspicuously as a good opportunity to make both a necessary improvement and a sound investment.

Reviewing the progress made in a short twenty-year period, we have seen the steam turbine and electric generator drive the reciprocating engine from the stationary power field. The same replacement is now taking place on our ships, big and small, notwithstanding the fact that the marine reciprocating engine is a very good engine indeed and operates under ideal conditions of steady load and constant speed. And now the steam locomotive must in turn give way to the electric motor for the same good reason that the reciprocating steam locomotive has become obsolete and equipment and congestion of tracks, what we need, in addition to constructive legislation and real co-operation on the part of the Government in the matter of rates and safeguarding invested capital, is wise direction in the expenditure of the large sums that must speedily be found and used to bring our railways abreast of the times. Accord full honor to the reciprocating steam engine for the great part it has played in the development of our railways and industries, but complete the work by replacing it with the electric motor and enter upon a new era of real railroading, not restricted steam engine railroading.

A careful study of the seriously congested tracks of the Baltimore and Ohio Railroad between Grafton and Cumberland disclosed vitally interesting facts.

Company coal movement in coal cars and engine tenders constituted over 11 per cent of the total ton-miles passing over the tracks. In other words, due to the very broken profile of this division, the equivalent of one train in every nine is required to haul the coal burned on the engines. Taking advantage of this

FIG. 10—NEW YORK CENTRAL LOCOMOTIVE—LATEST TYPE

fact and the higher speed and hauling capacity of the electric locomotive and its freedom from delays due to taking on water and fuel, it is estimated that the three tracks now badly congested with present steam engine tonnage could carry 80 per cent more freight with electric locomotive operation. The coal output of the

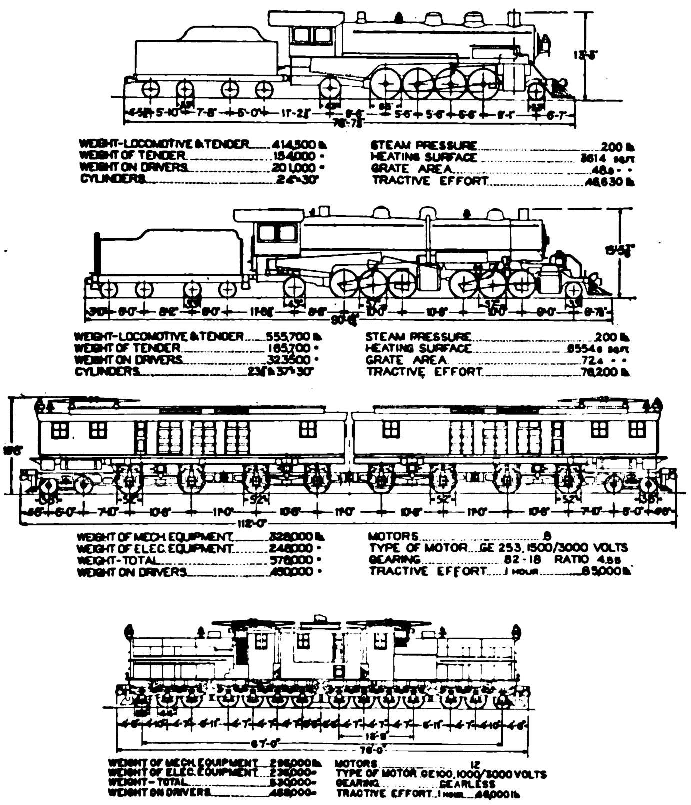


FIG. 11

Fairmount District is largely restricted by the congestion of this division of the B. & O. R. R. and it is probable that equal relief with continued steam engine operation could not be secured without the expenditure of a much larger sum for additional track facilities than would be needed to put electric locomotives upon the present tracks.

PROPOSED METRIC LEGISLATION

Agitation has again been started on the subject of the Government's use of the metric system. The bill covering the proposed plan has not been introduced to date during this session of Congress. It is contemplated that a bill similar to the last metric system bill may be introduced in the near future. It is understood that the proposed legislation will not be put into final form until after the Patents Committee has considered a brief of the arguments in opposition to be submitted by the American Institute of Weights and Measures. If in the light of these arguments it is still found feasible to push such legislation a hearing will probably be given interested parties. The last hearing on this subject was held about fifteen years ago, although the bill in a slightly different form has appeared before practically every session of Congress since that time.

Some few interests have aligned themselves in support of this measure, but it is expected that much opposition will be brought from the manufacturers of the country during the hearings, because it is realized that although the bill may provide for the adoption of a metric system in only the Departments of the Government, the eventual change-over, which would be sure to come, would be a tremendous expense to every phase of industry. The opposition will point out the fact that with industry and foreign trade in its feverish condition the country can ill afford such a radical change.

No doubt but that you have been flooded with congratulations on the success of the JOURNAL,—Your task is a great one, and you may even feel that your pay is small, but no one can estimate the value that such a publication will be to the Electrical Fraternity as the days go by. You may rest assured that your efforts will receive their reward through the greater service the JOURNAL will be to the vaster number of men who will read it.

The issue is just as it should be and I assure you that men will contribute to a live JOURNAL like that, who before would turn a cold ear to any such appeal.

Thanking you again most heartily for the results you have achieved, and the obstacles that you have overcome, I am, BYRON T. MOTTINGER,

Philadelphia, Pa.

Allow me to congratulate the Institute on the appearance of the JOURNAL. I feel sure that after the members of the Institute become accustomed to the new size, it will be universally approved.

CHAS. R. RIKER, Pittsburgh, Pa.

I am much pleased with the new JOURNAL of the A. I. E. E. It will be particularly useful to teachers and students of electrical engineering, as well as to practicing engineers.

A. S. HILL, Orono, Me.

Economical Supply of Electric Power

For the Industries and the Railroads of the Northeast Atlantic Seaboard

BY W. S. MURRAY

Consulting Engineer, New York City

Contributions to Symposium by:

(1) W. Le R. EMMET, Consulting Engineer, General Electric Co.
(2) J. F. JOHNSON, Engineer Turbine Department, Westinghouse Machine Co.
(3) H. G. REIST, A. C. Engineering Dept., General Electric Co.
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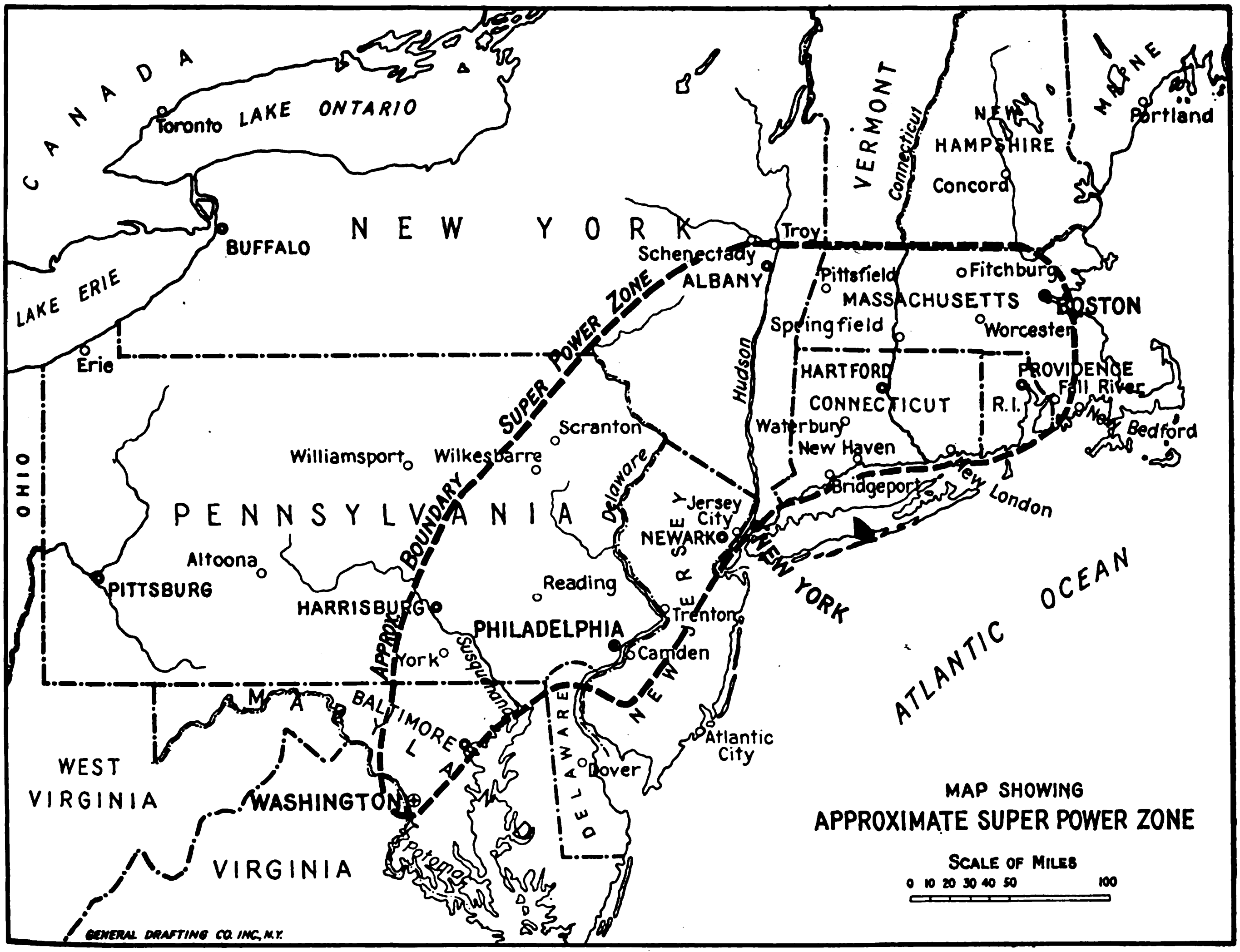
(6) PHILIP TORCHIO, Chief Electrical Engineer, New York Edison Co.
(7) PERCY H. THOMAS, Consulting Electrical Engineer, New York City.
(8) W. D. A. PEASLEE, Electrical Engineer, Jeffry-Dewitt Insulator Co.
(9) A. O. AUSTIN, Chief Engineer, Ohio Insulator Co.

THE super-power plan, briefly summarized, provides a means by which a present estimated machine capacity of 17,000,000 horse power—divided 10,000,000 for industrial purposes and 7,000,000 for the railroads—in a region between Boston and Washington and inland from the coast 100 to 150 miles, now operating with a load factor not exceeding 15 per cent, can be lifted to a load factor of greater than 50 per cent and possibly to 60 per cent, and a means by which, conservatively speaking, one ton of coal will do the work of two, and the railroads within the above zone, and those carrying coal into that zone will be relieved of transporting one-half the amount of coal required for power and lighting purposes. In short, the value of machine capacity from a utilization standpoint will be increased three to fourfold, and coal resources for the purposes named conserved twofold.



Presented at the Midwinter Convention of the A. I. E. E., New York, February 19, 1920.

This means that a present plant capacity of 17,000,000 horse power can be replaced by one of not greater than 5,500,000 horse power, and that not less than 30,000,000 tons of coal per annum can be saved, which at $5.00 a ton will represent $150,000,000 a year.

Besides the above savings, two great departments of economy will be created; one applying both to the railroads and the industries, in the reduced cost of maintenance of machinery, and the other applying to the railroads alone, in the reduction of train miles, by virtue of this plan permitting consolidation of trains with resultant savings in train miles. It is estimated that these latter economies will effect a saving of another $150,000,000 annually thus making a total saving of $300,000,000.

The above are the direct savings as estimated from data collected from actual past operations of the specific order contemplated to be put into force in the zone under consideration.

The railroad situation in this country is too well known to hold any brief upon it in this paper. Not secondary to the concern of those private interests from whom the money has come to build and maintain them is that, now, of the people to whom their service means so much. Forgetting for the moment the much-mooted question as to who will own and control them, we cannot afford however, from a national standpoint, irrespective of ownership, operation or control, to overlook any means, large or small, which will be conducive toward reducing expense keeping the standard of American transportation upon its past high plane, and which will operate to hold the roads solvent.

This plan offers immediate relief from the present intolerable congestion by automatically increasing rail capacity without increasing track mileage. It also operates to reduce power equipment investment to å minimum. By the creation of an overhead common carrier system of power the present cargo space now required for industrial coal will be cut in half; train equipment in all classes will have its service factor doubled, and the present steam power equipment, replaced by electrical equipment, can be transferred to other divisions, where it is so vitally needed.

The super-power plan has lately been given much space in the pages of the technical and public press, and except to say that it contemplates the general application of electricity wherever economically possible in the factories and on the railroads, in the zone described, it will not be necessary to add length to this paper by a more detailed description. It will doubtless engage your interest however, to know the following facts:

1. The plan has the unanimous endorsement of Engineering Council representing the American Institutes of Electrical, Mechanical, Civil and Mining Engineers.

2. It has been presented to and unanimously endorsed by the

a. Western Massachusetts Engineering Association
b. Bridgeport Chamber of Commerce
c. Connecticut Chamber of Commerce

3. It is now in Committee with the U. S. Chamber of Commerce, and so far as I know has found only favor in their considerations for the amount of time they have been able to give it among their many other deliberations.

4. Among the many prominent men with whom I have had opportunity to discuss it, including U. S. Senators and Representatives, Engineers, Central Station Operators and Railroad Officials, and Financiers, all have expressed the keenest interest in it.

5. An appropriation of $250,000 forms a part of the sundry civil bill to provide the money necessary to an investigation, under the direction of the Department of the Interior. This investigation will be followed by a report allocating the losses incident to labor and material by virtue of the present inefficient form of power production and distribution with recommended procedure, to cause their elimination.

While satisfied in my own mind that the true economy of power production, and its distribution in this great industrial and railroad field lies in an organized power policy, it is far more important that we should hear the opinions of those men to whom is largely due the great advances of electricity's application. Therefore, the following letter addressed to Messrs. Emmet, Johnston, Reist, Newbury, Porter, Storer, Torchio and Thomas will explain itself:

(I would add that the address referred to in this letter is one which was delivered to the Connecticut Chamber of Commerce and is reprinted in the JOURNAL of the A. I. E. E. for January 1920).

It has been said that the clash of rival systems has delayed the electrification of railroads. This, in my opinion, is true; but I question whether such a result, after all, has not been beneficial.

Fifteen years has been the period over which we have had opportunity to analyze the theory and practise of railway electrification.

Had we known fifteen years ago what we know today about electrification, and therefore could have decided the proper system to apply to each case, the financial stress under which the railroads were laboring would have prevented electrification.

Today the industrial demand for power has grown so prodigiously that faced with the old methods of power production which we have been perpetuating, we find ourselves faced with two factors, greatly militating against securing and maintaining supremacy in world's trade. Viz.: (1) throttled production, and (2) waste of the nation's natural resources.

The past fifteen years of education have opened the eyes of the "opposing camps" to certain fundamental factors which will now permit a prompt unanimity of opinion regarding what system applies. The railroad managers have in the past justly taken the ground that since we could not make up our minds which system was correct, they would wait until we could. But, as stated before, I believe that finance and not system has been the real cause of lack of action on the part of the railroads to electrify and that the delay has been truly beneficial since we can now stand on more solid ground for decision.

I am enclosing copy of an address made before the Connecticut Chamber of Commerce, November 19th, 1919.

While the super-power line as described in that address is an important adjunct to the plan proposed, the central idea is the indorsement of central station expansion through means of which national production may be increased and the conservation of our natural resources made secure.

As the major demand for power in the territory between Boston and Washington is for industrial purposes, I believe that I will be supported in the following conclusion:

(a) That prime generating machinery should be three-phase.

(b) That the power to be applied to railroads should be through synchronous motor generators with the synchronous motor fields designed to relieve to a maximum degree the direct current excitation of the prime generating machinery.

(c) That the question of whether train propulsion be by direct or by alternating current should be settled purely upon the economic relations existing between the generating side of the motor-generator substations and the driving wheels of the motive power. In saying this I realize that this robs the single-phase system of the argument to which it has justly laid claim by virtue of the higher efficiency of static versus rotative substations.

Railroad electrifications, in the past, have been individual to themselves. Today I believe that you will agree that they will form only a part of a whole and indeed be a smaller part, the industrial load being the greater—both receiving power from the same source.

I would like to be first under the above conditions in recognizing two serious limitations to single-phase generation.

(a) Size of generators.

(b) Low power-factor regulation.

The Paper's Committee have assigned the 18th of February during the Midwinter Convention in New York as the date for the presentation of a composite paper bearing upon the subject as presented in the accompanying pamphlet.

It is respectfully requested that you, as expert authorities in the design and application of the apparatus in your respective fields, keeping in mind the central idea of zone application of power, contribute your ideas, and while doing so, eliminate all thought of the past battle of systems.

I further believe that you will agree that the hour has struck for a united front and that such a paper will help the advance of electricity's rightful use in the industrial and railway field.

Since writing this letter contributions have been asked from Messrs. Peaslee and Austin, and their valuable opinions touching upon line and insulation form a part of this presentation.

To write a symposium of the contributions forming the principal part of this paper is at once both a delightful and easy task for there treads through such an effort the supporting element of unanimity of opinion. I shall not undertake to comment individually upon these authors' opinions, for that would be but a discussion of their papers. I will rather treat the subject as a whole, shaping its individual parts from the contributed opinions of the authors, using some cement of my own for coherence, and thus, I trust, arrive at a true composite summary.

I am immediately struck by what might be termed the composite voice of these authors. It is as though they say in unison, "We are ready and the conditions are ready to put this thing together." It is opportune here to quote from the address delivered by Past President Charles F. Scott before the New England Section of the National Electric Light Association, September 24, 1919: "The water powers which Nature has bestowed upon New England will be wastefully used until our best engineering abilities combine them into one great regional power system." Again, "The goal is the super-power system, the interconnection of hydraulic and steam stations—a single comprehensive power system, and the universal use of electric power"; and again, "A still larger view shows the power problem from New York to Washington to be closely related to that of New England. High-voltage transmission makes the region from Portland and Boston on the North to Baltimore and Washington on the South a single electrical area. The wide and more varied the field, the more favorable the diversity factor. Power plants at water powers, at coal mines and on tide-water at the cities, combined into one system insure the highest economy in power production."

Professor Scott shows by undeniable records of past growth of central stations, that if the present rate of increase is maintained in New England, its power requirement, now 1,500,000 kw. will be 5,500,000 kw. in ten years. What is true of New England is true throughout all the centralized industrial and railroad districts of the United States. The super-power system now so urgently needed here in the northeast will find demand elsewhere and related in time of application to the industrial and railroad density of the regions to be considered.

We have indeed come to the realization that electricity solved the problems of high-speed economic production and has become the agent of a tremendously diversified utilitarianism. I heard a representative of one of the larger electrical companies say he had just closed an order for a million motors for electrical washers. Think of this as a million kilowatt, and then think also of the diversity factor of such a load! This is but one illustration. The electric range, the toaster, curling iron—all these little implements depending upon electricity, integrate great power loads upon central stations. The amount of power a one-kw. washer takes in an hour would move a 40-ton freight car half a mile. Insignificant as the individual power application may be, their combination makes the central force to drive them immense.

Mr. Emmet more than confirms the statements made to the Connecticut Chamber of Commerce relative to the great economy of electric over steam locomotives and draws deserved attention to the more reliable operating characteristics of the electric engine over that of the steam during the winter months. Traction requirements in such season "go up" and the electric locomotive's capacity automatically "goes up" to meet them, while the steam locomotive's capacities when they are most needed "go down." Who has not had the experience when upon a steam train during bitter cold weather, of having his question,

"What's the matter?" answered by the conductor, "We can't make steam."

Mr. Emmet's contribution, though brief, not only brings out the fact that individual turbine sizes are now available for zone power application, and his closing paragraph, while summating important conditions to be satisfied, points to his belief that real results can be accomplished by cooperating in the art of power production—this to my mind is the crux of the situation, for if plant *A* is inter-connected with plant *B*, then the customers of district *A* and those of district *B* both can enjoy the fruits of economical power production, as upon those joint districts could be impressed the voltage from selected machines of high efficiency synchronized upon a common transmission bus.

In comparing the economy of present power production throughout the Boston-Washington zone, with the proposed super-power system, I have stated elsewhere that the former will average at least, if not more than, 40 lb. of steam per kw-hour, and that the average consumption per kw-hour for the super-power line will not be greater than 15 lb. In this connection it is most interesting to note Mr. Johnson's figures of ten, or even less than ten pounds of steam per kw-hour.

As Mr. Johnson has pointed out, "Constant output at as nearly as possible full normal capacity is the first requisite to high efficiency or its equivalent, low cost of production." This is but another way of saying that there can be selected from the inter-connected plants of those now operating and those to be built, the high efficiency units, their size and location related to required distribution, to supply the base load, with the governors of each machine set to contribute its power at highest efficiency.

It is indeed encouraging to find no qualifications in Mr. Johnson's viewpoint regarding the super-power system, but rather a reference to the specific nature of the apparatus necessary to produce satisfactory results, and especially his reference to the adaptability of the multi-cylinder type. It is quite clear that Mr. Johnson's shop specifications are ready and this department of the super-power system only awaits orders to construct. Mr. Emmet and Mr. Johnson have given us the assurances regarding the steam element in the super-power generator. What do Mr. Reist and Mr. Newbury say regarding the other half of the turbo-generators? Mr. Reist says: "So many generators of from 30,000 to 50,000 kv-a. are at present in operation, giving satisfactory results, that there need be no hesitancy in considering generators such as those now used or larger."

Mr. Newbury says: "The generating element in the proposed Boston-Washington power supply system does not involve anything new or untried. The individual power stations need not, and probably would not, be any larger than stations now in operation, or under construction: Certainly any probable station involved in carrying out this super-power development could be designed with steam and electric generating units of size now available."

Mr. Reist's remarks regarding the standardization of potential, methods of insulation and the closed cycle of ventilation are indeed illuminating and all point to that reliability of construction so necessary to continuity of service. It is surely a step in the right direction, and a mark of determination to save thermal losses when, as Mr. Reist points out, the generator itself is made to function as a feed water heater. It may be said indeed that this will be a clean and efficient way to accomplish generator ventilation.

Mr. Reist has opened up an interesting suggestion regarding the consideration of fifty cycles as a standard for world's frequency. Personally, I cannot offer a friendly port to this thought. I believe our generating and transformer investment in the two generally accepted standards of frequency *viz.* 25 and 60 cycles is of an order too large to change now. Certainly, generating equipment of 40 and 62½ cycles should be discouraged. In Mr. Thomas' presentation of the transmission and distribution problem for the super-power zone much valuable suggestion is offered to confirm the standard for prime generating power at 60 cycles.

I think Mr. Newbury has pointed out a fact, not to be denied, in saying that the "super-power scheme will have to be developed by building up local central stations. Its growth must be outward from these centers; but I believe he would agree in the importance of inter-connection of plants through high-voltage transmissions to secure not only diversity factor of load, but *economic* generation and transfer of power from one district to another. The operator who has tried to secure for his company the maximum number of kw-hours per annum from the minimum number of tons of coal burned, has indeed, many times been burdened with the thought of the low efficiency of some of the turbines in his plant that he has had to run on base load when a neighboring plant has had a machine lying idle whose efficiency was the equal of his best machine. Diversity factor though important pales in value when compared to this. That is one of the operating conditions I infer Mr. Emmet had in mind when he made reference to cooperation. I can easily conceive of a tie line between two plants without a single kilowatt of additional capacity paying a handsome return on the investment necessary.

Mr. Potter's able contribution on the traction side of the problem leaves but a small amount of cement to bind it to this symposium. He has furnished the cement along with his paper. In short, he tells us that every form of railroad service, passenger, freight or switching can be performed and better performed, by the electric locomotive. The record of electric motive power now in service doing terminal, level and mountain service, and the mileage electrified, bespeaks

[*Continued on page 308.*]

Submarine Detection in an Alternating Magnetic Field

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AND
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The paper describes a series of tests of the disturbance caused in a uniform alternating magnetic field by an incoming magnetic mass looking to the development of a device for the detection of enemy submarines.

Detection tests in the laboratory with submarine models 10 ft. long are in agreement with underlying theory and may be used as a basis for the design of larger equipment.

Detection tests on steel hulls from shore equipment and from equipment installed on a wooden submarine chaser 110 ft. long are in good agreement with results predicted from a formula developed in the laboratory tests.

By sufficient increases in the size of the equipment it is possible, in quiet water, to detect a steel vessel 200 ft. long at a distance of 500 ft. The weight of equipment required would be about 8000 lb.

Distances of detection in the neighborhood of 200 ft. were obtained in quiet water with equipment weighing 4500 lb. installed on a wooden submarine chaser 110 ft. long. The reliability of the system of detection is immediately impaired by motion of the vessel, due to her engines, heavy sea, and changes of course, or speed. The results mentioned involve the use of amplifier tubes for enlarging the signal. Without the amplifier the distances of detection are very short, even when a large magnet or large detecting coil and an extremely sensitive detecting instrument are used.

With amplifier, detecting coil and detecting instrument higher sensitivities may be reached than can be used in the detection tests. Disturbances in the detecting system fix the limit for increasing sensitivity. These disturbances are amplified and appear in the detecting instrument as larger than the signal sought.

Introduction

THE illegal and unforeseen methods of submarine warfare adopted by the Germans created an urgent demand for devices for detecting the hidden submarine. Practically no attention had hitherto been given to the development of such devices. So serious was the need that instructions were issued to government technical boards, requests to the national engineering societies, and a general invitation to the public to study the problem and make suggestions. As a result, hundreds of ideas, suggestions and plans were received through the several technical boards. Many of them were obviously worthless, and few, if any, from the nature of the problem gave promise of conspicuous success. A number of the more promising suggestions were developed experimentally and as based on the underlying physical principles they may be divided into two broad groups.

In the first group are the various methods of detecting sounds emitted by the submarine. These methods are more particularly adapted to the detection of the submarine at great distances. Devices of this character were brought to a high stage of development and extensive experiments were made with them. For obvious reasons data as to their performance is difficult to obtain,* but there is a general understanding that under favorable conditions the sound of the propeller or other machinery of a distant vessel can be detected at distances of several miles. One obvious limitation of these methods is that the enemy vessel may also be equipped with the same device and so can hear the approach of the searching vessel. Under these circumstances the submarine may come to a standstill or reduce its speed and noise to such an extent as to prevent the further estimate of its location by the searching vessel. A further disadvantage is the fact that the machinery of the listening vessel must be stopped during observations.

The second group embraces those methods which depend on the magnetic and electrical properties of the hull of the submarine. Most of these methods make use of the earth's magnetic field. The presence of the submarine disturbs the earth's field and effort is made to detect the distortion so caused. Other magnetic methods involve the establishment of an independent magnetic field by the searching vessel itself and the presence of the submarine is detected by the distortion of this field. The experiments which are to be described in this paper fall within this latter class.

The magnetic methods, by reason of the underlying physical laws, are adapted only to relatively short distances of detection. The strength of the magnetic field, due to a magnet, varies inversely as the cube of the distance from the magnet, and consequently the signal on a searching vessel received from a magnetized submarine falls off rapidly with increasing distance. On the other hand, the limitation of the listening device mentioned in the foregoing paragraph means that these methods cannot be used at short distances. Detecting devices therefore, having even a relatively short range, promised to be of value.

The experiments described in this paper aimed to develop a short-range magnetic detector. They were begun shortly after the entrance of the United States into the war, under the direction and support of the

*L'Illustration, February 8, 1919.

NOTE. The work described in this paper was carried out first at the Johns Hopkins University and then at the United States Naval Academy, under the direction of the Naval Consulting Board. The results of all the work have been communicated in a confidential report to the special Problems Committee on the Board, and permission has now been given for the publication of any portions which appear of purely scientific interest.

The body of the paper is generally descriptive in character and more detailed descriptions of the difficulties encountered and the methods of experimental attack are given in a series of appendices.

Naval Consulting Board. The fundamental idea on which the experiments were based was first suggested by Major (now Lieutenant-Colonel) Ralph D. Mershon, who was in general charge of the experimental work conducted by the Special Problems Committee of the Board. The first of the experiments were conducted in the Laboratory of Electrical Engineering of the Johns Hopkins University, and afterwards the work was continued on vessels afloat at the Engineering Experiment Station, U. S. Naval Academy, Annapolis, Md.

General Description

Of the various devices suggested for the detection of a submerged submarine making no noise, probably the simplest and most obvious are those making use of the magnetic and electrical properties of the hull. If the submarine comes into a magnetic field it becomes magnetized and consequently its presence may be detected by suitable measuring instruments. For example, if a detecting vessel carries a magnet or is itself magnetized, a submarine in its neighborhood will become magnetized. If the magnet be excited by alternating current, the magnetic field and the magnetization of the submarine will be alternating. A suitable detecting instrument on the detecting or searching vessel will then indicate the presence of the submarine, particularly if the instrument is compensated against the influence of the field of the magnet itself.

The principle of the device now described will be best understood from the following description by Lieutenant-Colonel Mershon:

> The most promising method so far proposed for the detection of submarines by an alternating magnetic field is this: An alternating magnetic field is set up by an alternating-current magnet having an open magnetic circuit;—a straight bar magnet so designed as to give as far reaching and as strong a field as is practicable. In the field of this magnet, and as far away from it as is practicable, is located a detecting coil. This coil may be located with its plane parallel to the lines of force set up by the magnet, in which case it will theoretically have no voltage induced in it by the magnet itself; or, it may be located with its plane not parallel to the lines of force, in which case the voltage induced in it by the alternating field set up by the magnet must be balanced out by another electromotive force exactly opposed in phase and magnitude to the voltage induced in the detecting coil. If the conditions aimed at are realized, there will, in either of these cases, be no resultant electromotive force in the circuit including the detecting coil, and no indication thereof in such means as may be employed for detecting an alternating e.m.f. in this circuit. If, now, a submarine comes into the field set up by the magnet, the submarine will disturb the field existing around the detecting coil, with the result that there will be an alternating voltage produced in the detecting coil circuit which will indicate the presence of the submarine, and may also indicate its location.

The current due to the electromotive force induced by the submarine in the detecting coil may be measured in a number of ways and in particular it may be rectified by a commutator mounted on the shaft of the generator supplying the magnet, and read on a continuous-current measuring instrument. The use of an alternating magnetic field and a commutator has a number of advantages. The system is independent of motion in the earth's magnetic field. It has a selective property, since the commutator will "chop up" disturbances of lower frequency. Under certain circumstances disturbances of higher frequency may be filtered out by suitable combinations of inductance and capacity. The signal e.m.f. is received in a detecting coil and an increase in the size of this coil affords one way of increasing the magnitude of the signal received from the submarine and therefore increasing the distance of detection. The e. m. f. in the detecting coil due to the magnet itself may be balanced out in a number of simple ways. Finally by means of the commutator a continuous-current detecting instrument may be used.

As is well understood, the strength of the magnetic field due to a magnet falls off very rapidly with increasing distance from the magnet. For distances large in comparison with the length of the magnet, the strength of field is inversely as the cube of the distance from the magnet; that is to say, the strength of magnetic field at the submarine will be inversely as the cube of its distance from the magnet. This is a serious enough limitation, but is only half the story in submarine detection. For detection of the presence of the submarine it is necessary that the magnetized submarine itself set up a field at the detecting coil sufficient to generate in that coil an electromotive force which may be detected by the usual available types of detecting instrument. This return signal from the submarine varies also inversely as the cube of the distance. Consequently, the signal in our detecting coil will vary roughly inversely as the sixth power of the distance to the submarine.

The relations outlined in the foregoing paragraph are at first sight most discouraging and indeed apparently insuperable. There are, however, several ways in which much of the handicap of the inverse sixth power may be offset. In the first place, the dimensions of the modern submarine are so great that its magnetic moment, even in a field of low intensity, may still be of appreciable magnitude. The signal received in the detecting coil may be increased by increasing the volume of the coil. The strength of the magnetic field at the submarine may obviously be increased by increasing the size of the magnet. And finally, we have now available in the three-electrode amplifier or pliotron tubes a means for stepping up a minute electric signal several hundreds of thousands of times. With the use of such tubes, it is theoretically possible to offset in large measure the limitation imposed by the inverse sixth power of the distance and to reach distances of detection which would be extremely important in submarine warfare.

It is obviously possible to compute approximately the moment of a magnet necessary for setting up a given field strength at a given distance, the size of de-

tecting coil for receiving a definite signal in a field of given strength, and the degree of amplification which may be given to such a signal by the use of amplifier tubes. It is not possible to predict however the magnetic moment of the hull of a submarine in a field of given intensity, nor to say what limits of amplification may be applied under the conditions of our problem. Experiment is therefore necessary before any safe conclusions can be drawn either as to the size of the equipment or as to its practicability.

As regards the magnetization of a submarine, if it were placed in a uniform magnetic field in the direction of its axis, it would still be impossible, owing to its unsymmetrical shape, the riveting of its plates and the uncertainty as to its interior structure, to make even an approximate estimate of its magnetic moment. Aside from this, the shell of the submarine when placed in an alternating magnetic field will have set up in it circulating or secondary currents. The magnetic field due to these secondary circuits will, in general, differ both in magnitude and in phase from that due to the magnetization of the hull. The relative importance and net magnetic moment due to these influences are obviously matters for experimental determination.

There is also another important and indeterminate factor. The detecting coil, in view of its position on the detecting vessel, will be relatively close to the magnet, consequently it will have induced in it a large electromotive force due to the magnet. This electromotive force must be balanced out and the coil be retained, as far as possible, in a neutral electric condition, for this is the condition of maximum sensitivity toward the signal from the submarine. This consideration demands as nearly as possible a rigid relation in space between the magnet and coil. On shipboard it is a question as to just how definitely it is possible to retain such a fixed relation. In considering this question it appeared certain that vibration and motion of a boat due to its driving machinery and to its rolling in a heavy sea would, to a greater or less extent, upset this desirable rigid relation between magnet and coil. The exact amount of this upset and whether it would be great enough to seriously impair the method were questions which could only be answered by actual tests on shipboard.

Experiments at Johns Hopkins University

Since the underlying relations of the method are reasonably clear, the uncertain factors being the values of the constants involved, the problem was first attacked by laboratory tests aimed to determine whether distances of detection which would be actually useful could be reached. Using the constants obtained in these laboratory tests, distances of detection for larger equipment were computed. Tests of this character were carried out in the Laboratory of Electrical Engineering of The Johns Hopkins University. These tests will be described first and the computations given upon which the design of the larger equipment was based.

The tests comprised studies of the types of magnet and detecting coils, of the method of balancing the electromotive force in the detecting coil due to the magnet, various types of commutator and detecting instrument, the use of amplifying tubes, the choice of alternating frequency, types of speed control and tests of the formulas by which the results to be expected in actual service were computed. Each of these investigations contributed to the design of the final equipment. The successive steps in each of these studies are of interest and value but have no necessary place in a direct statement of the experiments and conclusions of the investigation. Therefore only brief mention of them will be made as occasion requires.

The general arrangement of the essential elements is shown in Fig. 1 and the electric connections of the detecting circuit in Fig. 2. Referring to Fig. 1, S is a model submarine, M is the magnet excited by alternating current, C is a detecting coil and C' a balancing coil. Two arrangements of the relative positions of S, C and M are shown, these being the two most important from the standpoint of detection at a distance.

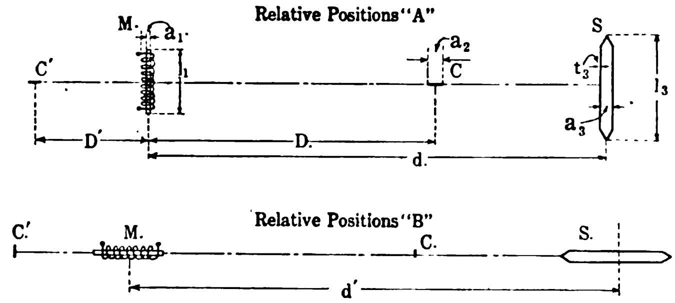


Fig. 1—Laboratory Tests

Submarine Model S. The model was made of galvanized iron 0.025 in. thick. It was cylindrical in shape with conical ends, the altitude of these ends being 1 ft. The length overall was 10 ft. and the diameter 1 ft. The length, diameter and thickness of wall are in approximately the same ratios as those pertaining to a late type of submarine of length 200 ft. There were five sections in the model, including the ends, the joints being telescoped without soldering.

The submarine model was mounted on a small wooden truck rolling on a graduated wooden track, thus permitting approach of the submarine to the detecting coil and magnet, and measurement of the distance at which a standard signal of detection was received in the detecting instrument G.

Submarine models of other dimensions and characteristics were also used, and an extensive study was made of the influence of variation of dimensions of the model on the signal received.

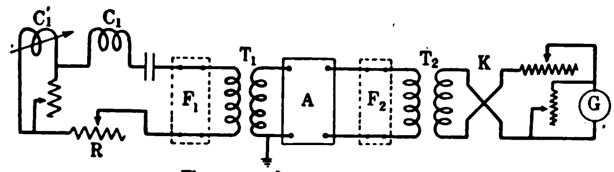
The Magnet M_1. The magnet M_1 had a laminated iron core 6 ft. long and 8.81 sq. in. (66.8 sq. cm.) cross

section. The core was bolted together and wedged in a piece of 4-in. internal diameter fiber conduit, over the outside of which the exciting winding was placed.

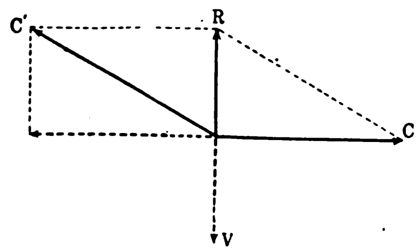
The exciting winding consisted of 28 coils, each having 52 turns and all connected in parallel. The coils toward the poles had a progressively increasing cross section of copper. The total length of the winding was 69 in., thus leaving a polar extension of the core of 1.5 in. at each end. The object of this method of winding was to maintain the flux in the core uniform over approximately its full length, thus increasing the effective length of the magnet.

At 30 cycles the magnet absorbed 200 amperes at 22.6 volts, *i.e.*, 4.52 kv-a. The power factor was 0.2. This excitation was used in the tests described below.

The Detecting and Balancing Coils. A number of coils of different sizes and characteristics were used as the detecting coil and as the balancing coil. The two coils used most commonly were of the same dimensions, having an outside diameter of 9.5 in., inside



– Elements of Detecting Circuit –



Emfs. of Detecting Circuit

FIG. 2

diameter of 5.75 in., the detecting coil, C_1 having 2000 turns of No. 22 B. & S. wire, and the balancing coil C_1' 306 turns of No. 14 B. & S. wire. The resistance of the detecting coil was 70 ohms and its inductance 1 henry.

As indicated in Fig. 2, the detecting and balancing coils are connected in series. The electromotive forces in the two coils are in opposition and the purpose of the balancing coil C_1' is to counterbalance exactly the electromotive force induced in C_1 by the field of the magnet. In this condition there is no current in the detecting instrument and an incoming submarine upsets the balance, causing a current in the detecting circuit and detecting instrument. Obviously, if C_1' is placed relatively near the magnet, it need have fewer turns relative to C_1. In this way the countersignal in C_1' due to the magnetized submarine is reduced to a negligible value.

The Generator. The generator was a 50-kv-a., 240-volt, single-phase, 60-cycle machine, directly connected to a 240-volt, d-c. compound-wound motor. The preliminary experiments having shown that the method was most sensitive at frequencies near 30 cycles, it was necessary to drive this machine at half speed. This was done by reducing the voltage on the motor armature running the fields of both motor and generator at approximately full excitation.

Mounted on one end of the shaft of the generator was the commutator for rectifying the signal delivered to the direct-current detecting instrument G, Fig. 2. This commutator was carefully constructed. It had six segments corresponding to the number of poles of the generator and the segments were separated by very narrow mica insulation which with narrow brushes permitted very close adjustment of the brushes with references to the zero of the alternating current. Worm and gear fitting for the brush holder aided in this accurate adjustment.

The Detecting Circuit. The simplest arrangement of the detecting circuit consists of the detecting and balancing coils, and the detecting instrument with its commutator all connected in series. With this arrangement it is possible to obtain a good balance of the system, but the distance of detection is quite small. With a detecting instrument of a given sensitivity, the distance of submarine detection can be increased only by increasing the sizes of the magnet and detecting coil. The tests with these simple elements of equipment and the computation in connection with them, indicate that an increase of the distance of detection by this means soon involves prohibitive sizes and weights for the magnet and coil.

It is important therefore that the sensitivity of the detecting instrument be increased so that signals corresponding to greater distances of the submarine may be detected. However, great sensitivity in the instrument itself usually means delicate construction and a thread suspension and these are not suitable for use on shipboard.

Fortunately, it is now possible in effect to increase the sensitivity of a rugged type of instrument to figures which are quite beyond those pertaining to the most delicate laboratory instruments. This is accomplished by the use of amplifier or pliotron tubes, now in common use in telephony, telegraphy and radio transmission. The properties of these tubes are now well understood and they need not be described here. They serve in effect a relays, in which extremely small amounts of energy in the form of electric signals may be used for liberating correspondingly greater signals from a local circuit, and transmitting them to the detecting instrument. The combination of amplifier and detecting instrument therefore results in a sensitivity far beyond that of the instrument alone, so that a rugged and substantial type of instrument may be used—a very important feature for service on shipboard.

The essential elements of the detecting circuit are shown in Fig. 2. C' is the balancing coil with an ad-

justable resistance across its terminals. It is connected in series with the detecting coil C_1 with a condenser C, with a frequency filter F_1, a transformer T_1 and a control resistance R. The transformer is for the purpose of adapting the characteristics of the detecting circuit to those of the amplifier A. For a given disturbance in the detecting circuit the maximum signal in the transformer will be obtained when the inductive reactance of the detecting circuit is neutralized by capacity C and the resistances of the detecting coil and transformer are equal. The total voltage generated is then divided equally between the detecting circuit and the circuit to which it is connected. The same considerations apply to the output circuit of the amplifier in its relation to the detecting instrument G. The transformers T_1 and T_2 are for the purpose of introducing receiving and delivery circuits of impedance approximately equal to those pertaining to the detecting circuit and detecting instrument respectively. The filters F_1 and F_2 consist of combinations of resistance, inductance and capacity and are for the purpose of cutting out disturbing frequencies above 30 cycles. The amplifier was arranged so that any number of stages from 1 to 5 might be used.

The Detecting Instrument. The most satisfactory type of instrument, as developed by experience, has been found to be a direct-reading, needle-type, double-pivot D'Arsonval galvanometer with zero in the center of its scale. The instrument most used in the present experiments was of this type and had a sensitivity of 10^{-6} amperes per millimeter of scale. It had a scale of 25 millimeters on each side of the zero position. The resistance of the instrument was 100 ohms and the critical dampening resistance 90 ohms.

In efforts to introduce the greatest sensitivity by means of the instrument, other types were also used, as for example, the Einthoven string galvanometer, a high sensitivity electro-dynamometer and sensitive suspension types of D'Arsonval galvanometer. These instruments are in general unsatisfactory by reason of their delicate construction. Not only does this construction render them unsuitable for use on shipboard but the circuit in which they are connected contains the coils C_1 and C_1', in each of which a very large electromotive force exists. During the process of balancing, there are frequently liberated in the detecting circuit electromotive forces of magnitude far beyond that of the signal to be detected. With an instrument of delicate suspension extreme caution is necessary to avoid disastrous consequences. The instrument mentioned above combined ruggedness and sensitivity to an unusual degree and withstood many hard knocks without damage.

The Experiments. The principal problem in the taking of observations is to secure and to maintain an exact balance of the electromotive forces set up in the coils C_1 and C_1'.

It was found by separate experiment that the phase of the signal received from the submarine is practically coincident with that of the main magnetic field due to the magnet. The brushes of the commutator therefore must be set so as to correspond with the electromotive force induced in C_1 by the main magnetic field. This is readily accomplished by cutting out C_1' and inserting enough resistance in the detecting circuit to insure that the resulting current is in phase with the electromotive force and at the same time that the current in the detecting instrument is within its capacity. This being done, the brushes may be adjusted for zero deflection of the measuring instrument, when the signal will be cut up into an equal number of positive and negative parts. A shift of the brushes by 90 electrical degrees will now bring their setting to the point corresponding to the maximum signal due to C_1 alone.

The problem of the balance is to introduce from C' an electromotive force exactly equal in magnitude and opposite in phase to that in C_1. Unfortunately the phase in the magnetic field of the neighborhood of the magnet differs appreciably from point to point. It is relatively easy to find a position in which the value of the electromotive force in C_1' is equal in magnitude to that of C_1, but quite difficult to find a point at which their phases are exactly the same. This was the most difficult of all the problems arising in the experiments. An extensive series of investigations was made on the method of balancing and it was found that the simplest and most accurate method was to adjust the phase of the electromotive force at the terminals of the balancing coil C_1' by varying its shunt resistance. (See Fig. 2). The value of the balancing electromotive force could then be varied by rotating the balancing coil about an axis normal to the direction of the field. The technique of the method is given in Appendix E.

The degree to which the equality of both magnitude and phase of the two opposing electromotive forces is obtained is measured by the constancy of the zero position of the pointer of the galvanometer. If they are not in phase slight changes of frequency will cause sharp upsets of the balance. Naturally it is more and more difficult to obtain a balance the greater and greater the degree of amplification that is used. In fact the limit of sensitivity of the whole apparatus is found by increasing the number of stages of amplification. With increasing amplification the wandering or jerks of the needle about the zero position become greater and greater and more and more irregular until finally they will mask the deflection due to the incoming signal. These disturbances of the balance are largely associated with variations of the speed of the generator. The greater the refinement in the control of the speed, the greater the degree of amplification which may be used, and consequently, the greater the sensitivity of the apparatus and the greater the distance of detection. A further description of the experiments on the balance in the detecting circuit is given in Appendix E.

The general method of taking observations was to

obtain a satisfactory balance, and then bring the submarine model toward the detecting coil until a standard signal was received, the distance from the magnet being observed. Throughout the experiments the distance of detection was measured between the centers of the magnet and the submarine. The readings were repeated sufficiently often to be certain of the distance of detection. The standard signal in these laboratory experiments was 15 millimeters of scale with a zero disturbance not greater than plus or minus five divisions. In general a ratio of signal to zero disturbance, 3 to 1, has been adopted throughout the experiments.

Experimental Results. Numerous experiments with both arrangements of Fig. 1 and with and without the use of an amplifier were conducted. Quite satisfactory observations were obtained without the amplifier and with the amplifier using up to three stages. Beyond this point, even under the most careful control of all conditions, obscure disturbances were magnified by the amplifier to a point where they were comparable with the ordinary signal due to the submarine model and therefore masked them. With prolonged investigation of the source of these disturbances and under carefully chosen conditions it was found possible to work with four stages of amplification. The conditions are quite unstable, however, and difficult to obtain; the results were therefore considered to be unsuitable as a basis for prediction of future results.

Without the use of amplifier the distances of detection of the model S were relatively small. Detection was definite at 15 ft. from center of magnet to center of submarine model, but 10 ft. with a galvanometer deflection of 1 cm. was taken as the conservative maximum distance.

With three stages of amplification distances in the neighborhood of 50 ft. were obtained, and for the standard signal on the galvanometer the distance, by a number of observations, was 44 ft.

Possible Distance of Detection as Estimated from Laboratory Tests

The results of the laboratory tests were made the basis of a computation of the distances of detection to be expected with enlarged equipment and the full-sized submarine.

The magnetic field strength or intensity due to a bar magnet at a point on its axis is

$$f = \frac{2\,M}{d^3} \tag{1}$$

and at a point on a line normal to the axis and passing through the center of the magnet

$$f' = M/d^3 \tag{2}$$

where M is the moment of the magnet and d is the distance of the point from the center of the magnet; d is assumed to be large compared with the length of the magnet.

Let l_1 and a_1 be the length and diameter of the core of the magnet M Fig. 1; l_2, a_2, t_2 and V_2 the length, mean diameter, radial thickness and volume, respectively, of the detecting coil C_1; and l_3, a_3 and t_3 the length, diameter and thickness of shell, respectively, of the submarine.

Let the magnetic field intensity at S due to M be f_1, then in either arrangement of Fig. 1, if the magnetic flux density in the core of M has always the same value

$$f_1 = K_1 \frac{l_1\,a_1^2}{d^3} \tag{3}$$

also the field intensity at C_1 due to S will be

$$f_2 = K_2\,f_1 \frac{l_3\,a_3\,t_3}{(d - D)^3} \tag{4}$$

This assumes that the whole length of the submarine is subjected to the same magnetic intensity and that the resulting flux is proportional to the cross section of its skin, that is, to the product of its mean diameter and the thickness of its plates. These assumptions are obviously open to question, but they are approximately correct when d is large compared with l_1 and l_3. Independent experimental studies of this relation were made particularly for values of d comparable with the length of the submarine. See Appendix D.

The electromotive force induced in the detecting coil will be proportional to f_2 and will also depend upon the dimensions and number of turns in the coil. The signal on a given detecting instrument will be a maximum when the resistance of the detecting coil is equal to that of the instrument and when the reactance of the coil is completely neutralized. We will assume then that the resistance R of any larger detecting coil will have the same value as that of the coil used in the above experiments. This value was approximately equal to the resistance of the detecting instrument used. We have then if l is the axial length, t the radial depth, a the diameter, and n the number of turns in the coil C_1

$$R \propto \frac{\pi\,a\,n}{\frac{l\,t}{n}} = \text{const.} \tag{5}$$

$$\therefore n = K \sqrt{\frac{l\,t}{a}} \tag{6}$$

The e. m. f. in the detecting coil e is

$$e = k_1\,a^2\,n \tag{7}$$

$$= k_2\,a^2 \sqrt{\frac{l\,t}{a}} \tag{8}$$

$$= K_3\,a\,V_2^{1/2} \tag{9}$$

Thus the e. m. f. or signal in the detecting coil due to the magnetic field f_2 set up by the submarine will be

$$S = K_1\,K_2\,K_3 \frac{l_1\,a_1^2\,a_2\,V_2^{1/2}\,l_3\,a_3\,t_3}{d^3\,(d - D)^3} \tag{10}$$

and if an arbitrary constant signal in the detecting instrument be selected, the distance of detection for any magnet, coil and submarine is

$$d = D/2 + \sqrt{K\,(l_1\,a_1^2\,a_2\,V_2^{1/2}\,l_3\,a_3\,t_3)^{1/3} + D^2/4} \quad \textbf{(11)}$$

By substituting in the above expression the distances of detection, the dimensions of the magnet, detecting coil and submarine model, used in the experiments described above, the value of K may be found and d may then be computed for any size of magnet, coil and submarine by substituting the proper values for l_1, a_1, a_2, etc. Obviously in this method of computing d it is assumed that the magnetic flux density in the core of the large magnet is the same as that in the core of the small magnet M_1 used in the experiments.

In the above development, no account has been taken of the signal in the balancing coil C_1'. In all of the experiments the number of turns in this coil has been small compared with the number in the detecting coil and its area has also been relatively small. In order to obtain the value of the electromotive force necessary to balance that in the detecting coil, it has only been necessary to place the balancing coil nearer to the magnet. Simple computation shows that in all the experiments the countersignal in the balancing coil C_1' due to the submarine was in all cases negligible compared with the main signal in C_1.

Making the substitutions mentioned above for the case when the amplifier is not used, and using the foot as the unit of length, a value of K, 31.3, is obtained which enables us to predict the possible distance of detection with the simplest elements of apparatus; that is, no amplifier being used. A submarine of recent type may be assumed as having a length of 200 ft., average diameter of 20 ft. and a thickness of skin 0.03125 ft. Substitution in formula (**11**) of these figures shows that in order to obtain even moderate distances of detection quite large sizes of both magnet and detecting coil would be necessary. For example, with a magnet 25 ft. long and core 1 ft. in diameter and a detecting coil 10 ft. in diameter and 9 sq. in. cross section, and a distance of 50 ft. between the magnet and detecting coil the distance of detection is found to be 185 ft. which is too short to be of value. Bearing in mind the equipment necessary to excite so large a magnet and the space requirements for the magnet and coil, it will be seen that the device promises little value unless the magnitude of the signal can be greatly increased, thus permitting a smaller size and mass of equipment and at the same time a greater distance of detection.

The outlook is considerably improved when we consider the tests in which the amplifier was used. When the distances obtained in these tests are substituted in formula (**11**), the value of the constant K is increased to 7730 approximately 25 times. Using this value, together with the constants of a submarine given above it was found that with a magnet 16 ft. long, 9 ft. in diameter and a detecting coil 7 ft. in diameter and 9 sq. in. radial cross section, distances of detection of from 450 to 500 ft. are indicated. These results were considered to be sufficiently promising to warrant the construction of enlarged equipment and further tests on actual vessels.

Experiments At Annapolis

Particularly favorable conditions were found at the Engineering Experiment Station, Annapolis, for conducting some intermediate tests on actual steel hulls of full size, without the necessity of diverting from other purposes a vessel on which the detecting apparatus would be assembled. In view of the uncertainty as to what bearing the character of the hull of a steel vessel would have on the results, it was deemed advisable to undertake experiments with enlarged magnet and coils and the use of steel hulls approximating those of the modern submarine, before going to the more elaborate and expensive equipment necessary on shipboard.

The detecting coil, magnet, motor generator, etc., were assembled on the end of a pier reaching into deep water and well removed from possible disturbing influences. The Experiment Station offered complete facilities for the construction and assembly of much of the necessary equipment. Electric power was also available in ample quantity.

In order that all factors entering might be made as large as consistent with their convenient usage, and so increase the maximum distance of detection, it was determined to build a magnet with the largest possible moment with an excitation of 26 kv-a., the limiting capacity of the available motor-generator set. This magnet which we will call M_2 had an effective length of 16 ft. and an overall diameter of approximately one foot. Its weight mounted on its base was 4000 lb.

The detecting coil C_2 constructed for these experiments had a mean diameter of 7 ft. and a winding cross section 3 in. by 3 in. It contained 1307 turns and had a resistance of 60.7 ohms and an inductance of 8.22 henrys. Its total weight mounted in its frame was 1500 lb.

The balancing coil C_2' was 3 ft. in diameter with a winding cross section 2 in. by 2 in. It had 530 turns and 9.86-ohms resistance. This coil was adjustable about a diameter arranged as a vertical axis. Its exact position could be accurately controlled and set by means of a worm screw and gear. Its weight in its mounting was 525 lb.

The motor-generator set with its speed control equipment, used in the Johns Hopkins University tests, was also used at Annapolis. In all other particulars as regards amplifier and other auxiliaries the apparatus was assembled and operated in the same manner as pertained to the Baltimore experiments. In these experiments which can only be mentioned here, many new conditions attendant upon the enlarged equipment were encountered. In particular much new information as to the detecting circuit, the importance of speed

control, and the elimination of disturbances was obtained.

The vessels on which the detection tests were made were the ocean tug "Standish" and the converted yacht "Wasp". Their respective dimensions are as follows:

Standish: Length overall, ...150 ft.
Beam, ... 27 ft.
Depth, ... 11 ft. (from deck to keel)
Skin, wrought iron ½ in. thick,
Wooden deck on steel frames 18 ft. apart.

Wasp: Length overall, ...203 ft. 9½ in.
Beam, ... 23 ft.
Depth, ... 18 ft. (from rail top to keel)
Skin, steel ⅝ in. thick with additional armour belt amidships 55 ft. long, 6 ft. wide and 1 in. thick.

The pier at the Experiment Station projected toward deep water and had a dock or basin alongside. The detecting coil was set up on the extreme corner of the pier and the magnet placed in various relative positions. The balancing coil was shifted to various convenient positions in relation to the magnet, and close to the balancing coil a small observing platform, protected from the weather, carried the detecting instrument and balancing equipment. The amplifier and the motor generator for exciting the magnet were located nearby in the Station, permitting ready access for commutator setting, speed control, inspection of amplifier. etc.

In taking observations a satisfactory balance of the detecting instrument was first obtained by the method described in Appendix E. A wig-wag signal was then sent to the vessel to approach on a prearranged course. Her position at all times was observed by a simple system of triangulation. When the signal was received on the detecting instrument the observer near the balancing coil signalled by means of a bell and the position of the vessel was thus noted at the corresponding moment. A corresponding signal was generally taken as the vessel passed out of range.

A large number of detection observations were taken with both arrangements indicated by Fig. 1 and with the vessel approaching on different courses. The maximum distances of detection reached were in the neighborhood of 450 ft. and were therefore in general accord with those predicted from the laboratory tests in the manner indicated. Fig. 3 shows graphically the results of one series of tests.

Detection Tests Afloat

It is obvious that the distances of detection which have been mentioned are dependent strictly upon the degree of sensitivity which is used in the detecting circuit. Throughout the experiments it was always found that in the combination of amplifier and measuring instrument it was possible to obtain figures for sensitivity higher than it was possible to use by reason of the limitations of the exact balance between the detecting and balancing coils. One vital factor affecting the balance is a fixed relation between the magnet, detecting and balancing coils. If any one of the three moves, with reference to the others, the balance is correspondingly upset. It was realized, therefore, considering further tests on shipboard, that there was a large chance that the distances predicted might be seriously curtailed, if not entirely lost, by reason of the vibration due to the engines of the vessel and to the straining or distortion of the hull of the vessel due to the motion of the sea. There appeared also a possibility that these factors might have an influence on the delicate relations obtaining in the amplifier tubes and on the detecting instrument. However, the unusual steadiness of the submarine chaser, as regards her engines, seemed to offer exceptionally favorable

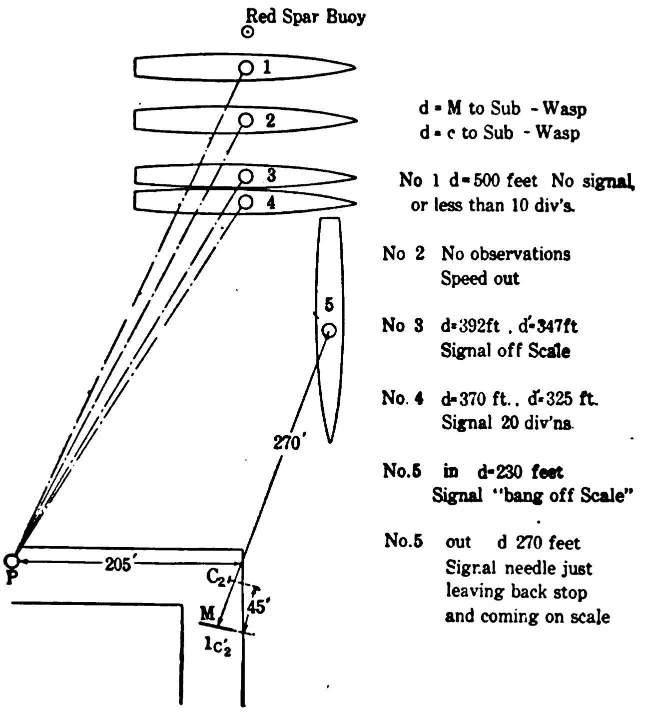


Fig. 3—Detection Tests—Yacht "Wasp"
Large Magnet and Coils.
3 stages and transformer.
10-ohm shunt. Excitation 93 amperes; 50 volts; 4.65 kv-a.
Distances Measured by triangulation from point *P*. Balance conditions good at constant speed; needle returned to center of scale after all signals.

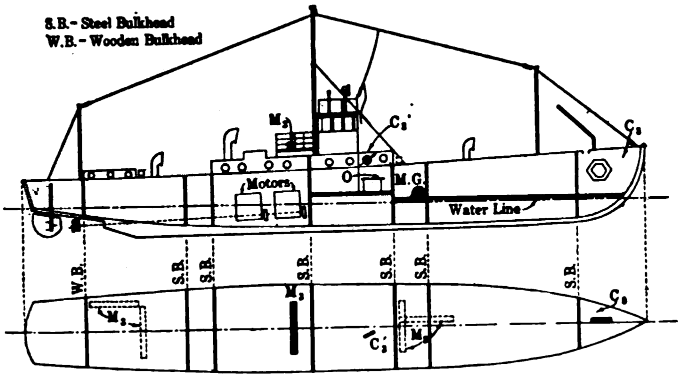
conditions in this respect. Moreover, a promising method of spring suspension for the amplifier and a robust detecting instrument which seemed to be independent of moderate motion also gave promise of partially avoiding the difficulties mentioned.

The submarine menace at this time was at its most serious stage. No reliable detection devices existed, and every possible chance for the development of such a device was being encouraged. Submarines are limited to about 200 ft. of submersion and it was felt that if half the distances obtained in the shore tests could be reached in reliable fashion the method might prove of value. In view of the good agreement between the computed and the observed distances in the foregoing experiments, it was therefore decided to

construct and install the equipment, described below, on Submarine Chaser No. 326, stationed at Annapolis and placed at the disposal of the Naval Consulting Board at the request of the Special Board of the New London Naval Experimental Station.

The total weight of the equipment used in the shore tests, 17,000 lb., was unnecessarily large, even for a magnet of the capacity of M_2. This was principally due to the fact that the motor generator was of higher rating than that of the magnet and no special effort had been made to limit the weight of several other portions of the equipment. Moreover, tests both in the laboratory and at the Engineering Experiment Station had shown that it was possible to obtain good results with considerably lower figures for the excitation of the magnet. This is in accord with theory, as the distance of detection varies approximately as the sixth root of the total flux emanating from one pole of the magnet. (See formula (**11**)).

The method requires the use of a wooden vessel. The number of such vessels available, of length greater



Scale—1 in. — 12 ft.

Fig. 4—Submarine Chaser, "S. C. 326"

than 100 or 150 ft., is very limited. The 110 ft. submarine chasers were seen to possess many features advantageous for testing this method. Not only have they wooden hulls, but they are driven by three gasoline engines of six cylinders each, and this feature results in extreme steadiness when under way. In addition it will be seen, from a description below, that the space on board was admirably adapted to the accommodation of the necessary equipment. A study was therefore made as to the maximum equipment which could be installed on one of the chasers, the magnet being limited to the capacity which could be furnished by a 3½-kw., 120-volt, d-c. gasoline-driven generator, installed on the chaser for pumping and other purposes. As based on tests on shore, it appeared that it should be possible, with this equipment, to reach distances of detection which would be useful though considerably less than those obtained with the larger equipment in the shore tests.

Submarine Chaser No. 326. The "326" (See Fig. 4) is 110 ft. long, 15-ft. beam midships and has an average depth from deck to keel of about 10 ft. She is of wooden construction throughout except that she has six water-tight steel bulkheads. Other metal masses are the engines, propeller shafts, rudder, ventilators, air and gasoline tanks, anchor, stanchions, deck posts, etc. Outline drawings of elevation and deck plan, shown in Fig. 4, indicate the construction of the vessel and the relative location of her equipment, the steel bulkheads, and the experimental apparatus.

The earlier experiments had shown that the proximity of masses of metal had no effect on the balance conditions as long as these masses were stationary. Several rough experiments were made in order to determine the influence of such masses and no striking influence was found. It was always possible to secure practically the same conditions of balance when the metal mass was present or absent.

It was recognized, however, that the steel bulkheads of S. C. No. 326 offered a condition which had not been considered in the earlier work. These bulkheads, stretching the full width of the ship, are longer than the magnet and no positions for the magnet can be found which are very far removed from some one of these bulkheads. The influence of the bulkheads therefore was an uncertain factor. Subsequently, a number of experiments were made to determine this influence and it was found that the phase of the magnetic field near the bulkheads was markedly affected by them, that the influence on the balance could be eliminated, and that the influence on the sensitivity, while appreciable, was not great.

The Motor Generator. The generator was a 5-kv-a. single-phase, 60-cycle machine, directly connected to a 220-volt, compound-wound, d-c. motor, operated at full excitation and half voltage, thus driving the set at one-half speed for 30 cycles. The power for the set was supplied by the 3½ kw. gasoline auxiliary set, already described, which was located in the engine room. The motor generator, together with all of its control equipment, was located in the magazine, as indicated at *M G*, Fig. 4.

On one end of the shaft was located the rectifying commutator of the detecting circuit. The other end was equipped with special control devices, including ball thrust bearings, for constant speed regulation, as described in Appendix B. There is no more important feature for a balance of high sensitivity in the detecting circuit than constancy of speed, and much time and effort were devoted to perfect the two speed control methods described in Appendix B.

The Magnet M_3. The core of the magnet was 9 ft. long and had a cross section of 7.7 sq. in. (49.5 sq. cm.). The core was placed inside a piece of 4-in. internal diameter fibre conduit, over the outside of which the exciting winding was placed. This winding consisted of six similar one layer coils of 104 turns each, No. 10 B. & S. cotton covered wire, all connected in multiple. The length of the core beyond the winding at each end was 15 in. The magnet was mounted in a suitable wooden frame and housing.

In Fig. 4 the magnet is shown as located on the bridge of the chaser just abaft the pilot house. Other positions in which observations were made are indicated in dotted line on the deck plan.

The Detecting and Balancing Coils C_3 an C_3'. Two features are desirable for the location of the detecting coil; one that it should be below decks, and the other that it should be as far as convenient from the magnet, the latter for its bearing on the conditions of balance. The location combining these two particulars to best advantage was found in the forward hold of the chaser. A serious drawback to this position was that entrance to the hold was limited to a manhole 18 in. in diameter in the deck. However as none of the hatches on the

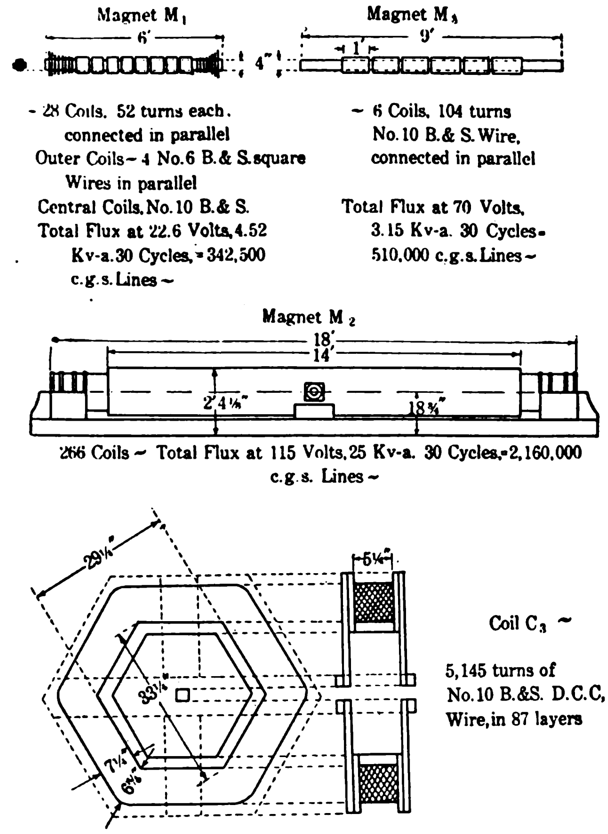


Fig. 5

vessel was large enough to accommodate a coil of the size required, it was realized that in any position below decks the coil would have to be wound in place.

The coil as finally wound was hexagonal in shape, this shape being adopted for convenience in construction and assembly of the wooden form on which the coil was wound and permanently supported. Its dimensions, shown in Fig. 5 were the largest possible in the available space, having in mind the importance that for the experiments it would be located with its plane athwartship, as well as at right angles to this position, and also that it should be kept a reasonable distance from the nearest steel bulkhead. In winding, the wooden form was mounted on an axis, and owing to the limited space, turned by hand. The wire reels were mounted on deck and the wire fed through the manhole. After completion of the winding the form was firmly braced into position, so that it became, as far as possible, an integral part of the framework of the vessel.

The coil had 5145 turns, average length of each turn 10.3 ft. corresponding to a circular diameter of 3.29 ft. The volume of the winding, V_3, was 2.6 cu. ft.

The balancing coil, C_3, was located inside the radio room of the chaser, which was used as the center of control and observation. Its location is shown at 0. Several different balancing coils were used at various times. They were all of small size, less than 1 ft. in diameter and were mounted in wooden frames, permitting accurate adjustment about a diameter as axis. Sometimes two coils were used, one of them located near the magnet to take up the greater part of the electromotive force in the detecting coil. The final balance, both as regards phase and magnitude of the net balancing e.m.f., was always accomplished from the observer's station, from which ready access could also be had to the rectifying commutator on the motor generator.

Practically all of the control equipment, including transformers, filters, condensers, switchboards, speed control and storage batteries, was located in the magaazine. The amplifier and resistance for the final adjustment of the balance were located in the radio room in convenient reach of the observer at 0.

All of the wiring was enclosed in steel conduit or other metal covering and all portions of the detecting circuit, transformers, speed control, etc., were placed in iron boxes for screening. Extreme precautions of this character were necessary, as any exposed part of the detecting circuit would pick up inductively stray disturbances difficult to recognize, and very troublesome when magnified by the amplifier.

Total Weight. The approximate weights of the several portions of the equipment are as follows:

Magnet,	420	lb.
Motor generator and control,	2000	"
Detecting coil,	1065	"
Amplifier,	150	"
Batteries and auxiliaries,	500	"
Total,	4135	"

As assembled, the only portion of the equipment appearing above decks was the magnet, whose housing was 10½ ft. long and approximately one foot square in section. The space occupied below decks was limited to the magazine, the radio room, and a part of the forehold.

The Tests. The experiments embraced a great many preliminary tests on the conditions and stability of the balance in the detecting circuit. The congested condition in the magazine, bringing as it did, the generator magnet, transformer and speed control in close relation to each other, introduced a number of new

disturbances. In addition, the motion of the boat, both as regards its vibration and rolling, were new types of disturbance. The phase of the magnetic field was found to vary in a most irregular way in different parts of the boat. Although the input transformer of the amplifier was enclosed in a triple nest of wrought-iron screens, it was found to pick up very large inductive electromotive forces. In some positions of the magnet M_3 these stray electromotive forces were so large as to be comparable in magnitude with that in the detecting coil itself.

As a result of all the new disturbing factors, the use of the input transformer was abandoned in the later tests and the amplifier operated at either three or four stages. Under the best conditions available on the boat therefore the sensitivity of the detecting circuit was reduced to from one-half to one-tenth the value used in the shore tests, depending on the motion of the vessel due to the sea. It was considered that this degree of sensitivity was surprising and highly satisfactory for the conditions encountered. It was accomplished largely through the reduction of the electrical equipment to its simplest terms, by careful spring suspension of the amplifier, the rigid mounting of the detecting and balancing coils and of the magnet, and especially to the close control of the speed of the motor generator.

It should be stated at this point, however, that the degrees of sensitivity, mentioned above, pertain to what would ordinarily be described as good sea and weather conditions. Motion of the boat in high wind and heavy sea is immediately reflected in the detecting circuit. Sudden changes in engine speed and sharp changes of course also introduced corresponding upsets of the conditions of balance.

The detection tests were made on the steel converted yachts Wasp and Vega. The dimensions of the Wasp have already been given. The Vega was 179 ft. long, 20 ft. beam and approximately 15 ft. depth from keel to rail top. The thickness of her skin could not be ascertained, and it is assumed to be the same as that of the Wasp, 5/8 in. The tests were made sometimes with the vessel to be detected lying at the dock and sometimes in the open waters of Chesapeake Bay. Three kinds of tests were made; one approaching the submarine end on, that is, along the common axis of the two vessels; one passing the submarine, the two axes being parallel; and the third approaching the submarine as though to ram her amidships. The distances of detection were read with a range finder, or "stadimeter," the observer standing close to the magnet M_3 The distances were measured to the center of the vessel to be detected. Two observers were required for making a test, one on deck measuring distance to the vessel to be detected, and one below at the instrument table. The detecting circuit was balanced with the vessel under way, and at some distance from the vessel to be detected. As the latter vessel is approached the galvanometer deflects and at a given magnitude of deflection the observer at the nstrument signals with a bell to the other on deck who records the distance. A great many tests of this character were made with various relative positions and speeds of the two vessels. It is not possible to make a more extended description of these tests within the limits of this paper.

The actual distances of detection reached, even under the best conditions, were usually somewhat short of 200 ft. In quiet water and at low speeds it was found to be possible to reach distances better than 200 ft., but this figure pertains strictly to conditions of this character. These figures fall somewhat short of the distances as computed for the equipment as installed. Two causes were found for the discrepancy.

At distances of 200 ft. between magnet and submarine the magnetic field due to the magnet is far from uniform over the whole length of the submarine. This results in a considerable shortening of the magnetic moment due to the hull of the submarine. A separate laboratory study of this condition showed that when a correction is made on this account, the observed distance of detection of 200 ft. is very nearly in accord with the computed distance.

A far more serious limitation to the distance of detection was found in the conditions of the balance, that is, in the instability of the zero of the detecting instrument. These conditions were strictly dependent upon the stability of the vessel and became rapidly worse the higher the sea, the more rapid the speed of the boat, and the balance was always sharply upset on any change either of the course or the speed. There was always available a considerably higher sensitivity in the combination of amplifier and galvanometer than it was possible to use, owing to the vibration and motion of the boat.

Considered from the standpoint of quiet water and slow speeds, the results of the detection tests on S. C. No. 326 were in accord with predicted values and they may be made the basis for the computation of the size of an equipment for extending the distances reached in the tests given above.

General Conclusions

The principal conclusions from the detection tests are as follows:

1. Detection tests in the laboratory with submarine models 10 ft. long are in agreement with underlying theory and may be used as a basis for the design of larger equipment.

2. Detection tests on steel hulls from shore equipment and from equipment installed on a wooden submarine chaser 110 ft. long are in good agreement with results predicted from a formula developed in the laboratory tests.

3. By sufficient increase in the size of the equipment it is possible, in quiet water, to detect a steel ves-

sel 200 ft. long at a distance of 500 ft. The weight of equipment required would be about 8000 lb.

4. Distances of detection in the neighborhood of 200 ft. were obtained in quiet water with equipment weighing 4500 lb. installed on a wooden submarine chaser 110 ft. long.

5. The reliability of the system of detection is immediately impaired by motion of the vessel, due to her engines, heavy sea, and changes of course, or speed.

6. The results mentioned involve the use of amplifier tubes for enlarging the signal. Without the amplifier the distances of detection are very short, even when a large magnet or large detecting coil and an extremely sensitive detecting instrument are used.

7. With amplifier, detecting coil and detecting instrument higher sensitivities may be reached than can be used in the detection tests. Disturbances in the detecting system fix the limit for increasing sensitivity. These disturbances are amplified and appear in the detecting instrument as larger than the signal sought.

8. The problem of increasing the distances of detection is that of eliminating disturbances in the detecting circuit.

9. Other interesting conclusions at various stages of the work will be found in the several appendices.

[To be concluded in the April Journal.]

The Engineer, Employer and Employee

BY CALVERT TOWNLEY

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THE purchase prices of most essentials, not to mention luxuries, of life are now abnormally high. Can the engineer do anything about it except pay and grin? My good friend, George F. Swain, of Boston, says that the engineer is the antithesis of the idealist and that the idealist is a most dangerous individual. The engineer approaches a problem with an open mind, first obtains all the available facts and then reaches his conclusion and bases his action on these facts. The idealist on the contrary, first pictures the ideal result which he would like to obtain and proceeds to make his facts fit—if they do not, so much worse for the facts. In discussing higher prices, let me see if I can qualify under Professor Swain's definition of an engineer. The first question that arises is "Why are prices high?" And the answer to this question is almost if not quite obvious. Prices are high because costs are high and costs are high because wages have gone up. Of course material as well as labor goes into cost, but material in the last analysis is very largely labor because, for example, coal, iron, copper, lumber and other raw materials, forming the bulk of those used, are governed as to their cost by the wages paid to produce them. It is also alleged, and with reason, that prices of some commodities are higher than the increased costs justify because their distributors have taken advantage of existing conditions to reap abnormal profits. This no doubt is so to a limited extent. It can hardly be claimed to be true in general and certainly not to such an extent as to disprove the statement that prices are high because costs are high. Following the analysis, if prices are high because costs are high and costs are high because wages have increased, the next question is "Why have wages increased and in what way, up or down, may wages be expected to change in the future?" We have all heard much about the "awakening" of labor and its determination to hereafter demand and obtain a greater "share in the reward of its products." Our recent history is not lacking in examples of efforts on the part of workmen to benefit through organization and collective bargaining, effects crowned with no mean measure of success, but of catch phrases and slogans it perhaps may be said that they lack a sufficiently definite meaning to be interpreted alike by all. A catch phrase can frequently be made to mean whatever its user wants it to mean over wide limits. Let us therefore adhere to a terminology of which the meaning is understood by all and which is always the same. First of all what do we mean by "labor" and "capital?" Perhaps we all ought to understand what these words mean but do we? If we say that "labor" is the performance of manual work and "capital" is accumulated money, it can be pointed out that many are classed with labor who do no manual work while a large number have accumulated money who are not capitalists. Possibly the walking delegate's definition would be that a laborer is one who works all the time for pay but never has any money and a capitalist is one who has money all the time but never does any work. Both of these are manifestly incorrect definitions. For the purpose of avoiding misleading terms perhaps we can dodge the issue by not using them in the present discussion and instead of referring to capital and labor speak of the "employer" and the "employee" although even then it becomes necessary to explain the term "employer" to include not only him who pays for the services of others with his own money but also him who directs the work of others while himself employed and also to limit the term "employee" to those who do not so direct the

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work of others. Is there any good reason to believe that a "new order" of things has been created that the working man or employee will hereafter "demand" and what is more to the point obtain a greater share of the reward of his labor and that therefore wages and consequently the cost of everything into which labor enters will stay up and may even go higher? Has there been anything which may properly be called an "awakening" of labor? The only evidence that I can find to support such an idea is the undeniable fact that beginning in 1914 the employee has demanded and has obtained a greatly increased wage and of course we know it is human nature to get all we are able and to keep it if we can. But these plain facts do not prove the reasons why. The working man like every other man has in the past always wanted all he could get and human nature to-day has neither gained nor lost cupidity. There is no indication of a "new order" in these facts.

It is conservative to look for ordinary and natural causes before evolving new theories so before wondering whether there is or is not any "new order" of things, suppose we examine the old order and see what could be naturally expected under it. Before the war the country was prosperous, general business was good, the employees if not contented and happy were at least much less discontented and unhappy than they are to-day and with wages very much lower than they now receive. Then came the war. The men of both sides threw down their tools and took up arms. The productive capacity of every warring nation was at once greatly reduced but their needs were not—they were greatly increased, and naturally the United States was called upon to help supply them. We were by no means the only but we were certainly by far the largest source of supply in the world and our productive capacity was immediately speeded up to meet the new and unusual demand made upon it. All this was natural, ordinary and logical and its analysis so simple as to seem very obvious. Then what happened? The business men of this country—the employers— those in command of industry saw their chance. They had, if not exactly a monopoly or corner, in the supply market at least something very like it and they promptly took advantage of the situation and boosted their prices. Higher prices for export to Europe soon reacted to cause higher prices at home and the complaint of profiteering started and spread. It reached such proportions as to influence the government and action was taken to curb the business man's cupidity and make him loosen up. To a considerable extent he did it; sometimes with not very good grace, but nevertheless as a class he recognized the logic of events and acquiesced. Then we got into the war ourselves and we likewise took several million men out of our shops to fight and in turn we increased our demand for manufactured goods and decreased our productive capacity. You will note that I say "productive capacity" not our output. That our actual output was greatly increased in spite of the reduction in capacity is history but the reasons for it were improved efficiency, concentrated effort etc., and do not contradict nor weaken the preceding statement. Well, what happened then? Why the workman—the employee—waked up. He began to do what the business man—the employer— did when the war began, and which caused the hue and cry against profiteering. He saw a diminishing supply of men and an ever increasing demand for work and he cornered his market. He put up the prices of his services and having got the new price easily he put it up again, and so on. You know the rest. Now all this seems to be natural, simple, logical and so obvious as not to need argument but it is all based not on any "new thought" or on the awakening "of the proletariat" or any other new ideas or theories but on the plain old fashioned simple law of supply and demand, a law as old as the hills and just as immutable.

I do not lose sight of the fact that the organization of labor played a conspicuous part in bringing about increased wages. Many people no doubt honestly believe that organization did it all. Well organization did a great deal of course. The organization was the machine tool or weapon which the employees used to get quicker and greater results. It is pertinent to remember however that the organization of workmen is not new. They have been organized for years. There is no essential difference between the way in which nor the extent to which they are organized now and what they have been for many years past. And ever since employees began to organize they have been trying to get higher wages by identically the same methods they have been using during the war period. But organization never before accomplished anything like the results which latterly have been brought about and it seems clear therefore that we must seek the cause for the great wage advances not in some old condition like organization which existed long before the war but in some new condition that has been created since the war began. That new condition is obviously a change in the relation of supply and demand and we get back to our first conclusion again as to why wages have so greatly increased. Another contributory cause is the decreased efficiency of the workman. Employees. as a class, do less work, produce smaller results per day's work than formerly. There seems to be abundant evidence of this condition; enough to warrant our accepting it as a fact. One reason of course is that the employers had to use "seconds." Just as a builder in times of stress will put into a house lumber that he would ordinarily reject; because he cannot get enough first class lumber and he *must* have the house, so employers were forced to hire men in war time that ordinarily they wouldn't have about the place; there weren't enough others. Then of course there is the question of fewer hours per day and a reluctance to work continuously through the week. These features materially affect the increase in cost. They effect it tremendously

but while in fact they may be important, they nevertheless are not causes at all but merely results incidental to the working out of the law of supply and demand. They are superimposed upon and do not underly the existing condition which we are analyzing.

Some say that the change in the value of the dollar has caused the increased cost. On all sides we hear and read the statement that the dollar is only worth fifty cents, or some other small fraction of its face, and that prices and wages are really no higher than they used to be because the dollar is now worth much less. Well suppose we briefly examine that statement. What is a dollar worth anyhow—by itself? Why a dollar isn't worth anything—by itself. You can't do anything with it—by itself. A dollar is simply and solely a convenient medium of exchange. It has become valuable just to the extent that men want it and will give up something which they have to get it. When we set out to place a definite value on the dollar in commodities or labor it isn't sufficient to take into account the conditions in one place only, in Schenectady, for example, or in a dozen or in fifty places, or even in any one entire country. The dollar has value all over the world now but when our economists insist that the value of the dollar has fallen permanently, they are evidently thinking in terms of conditions in the United States only. Abroad the situation is very different. A dollar will buy about six shillings in London, 1½ times its old rate; 15 francs in France, three times its old rate; 100 marks in Germany, 24 times its old rate, and the end is not yet. Travelers returning from Europe bring back specific information of how much more than formerly can now be bought with a dollar. Not only is foreign money cheaper but things are as well. For example in November last at the best hotel in Vienna, and its a good one too—the Hotel Bristol, a big room with three beds and a bath, occupied by three, the rate was the equivalent of 62 cents a day American money. Does that look like a depreciated dollar? And if it be said that this comparison is misleading because European exchange is only down for a while and the condition is therefore temporary, the answer is how do we know, how does anybody know that the values in the United States are any more stable or permanent? Instead of theorizing why not look to history for real information? The best indication of what will happen in the future is what has happened in the past. We have had wars before—not so big, not so many men were killed, but a very similar condition as to the supply of and demand for labor was created. This same condition of inflated values that confronts us now existed right after our civil war and it seems reasonable to attribute it to the same causes. In any event the high cost of living after the civil war was not due to the activities of labor organizations because they didn't exist then. The more we examine the cause for abnormal advance in wages from different angles the more it seems evident that the fundamental underlying and controlling cause has been an increased demand and a decreased supply. Now if the law of supply and demand has controlled the wages of workmen in the past and through them the cost and therefore the price of commodities, this same law is very likely to exercise this same control over the same conditions in the future. In other words prices will stay up, go higher, or fall according as the supply of labor is equal to, less than, or greater than the demand. You will have noted, I hope, that I have tried to discuss facts and conditions and have not referred to the so called "rights" of the interested parties, the employer, the employee and the public. That is another part of the story but it is my conception that the economics of industry will continue to be governed by economic laws which are just as immutable as are the laws of the attraction of gravitation and other physical laws albeit not so generally understood and acknowledged and that any so called "rights" of the different elements of society, no matter how skillfully or persistently asserted, must give way absolutely before the inexorable operation of economic laws. The question of "rights" is further one into which opinion enters more than demonstrable facts and no opinions of any party to such a discussion has received particular credence, much less acceptance from any opposing party. It would be profitless therefore in the present discussion to diverge into any attempted examination of this phase on the subject.

If now prices were raised to their present level because the war required greatly increased production and at the same time withdrew from productive occupations so large a number of workers, how will prices be affected by the operation of economic laws in the future? The war is over. War material is no longer demanded. Its production has ceased. The men who fought have been released to pursue again their pre-war avocations. Yet prices are still up where they were. If my reasoning is correct, why has the law of supply and demand not reversed its effect and operated to restore pre-war conditions? That question has to be asked to follow the analysis logically but its answer seems fairly obvious. Pre-war conditions have not been restored because there hasn't been time. In this country during the war we couldn't and didn't produce what was needed. We produced all we could selecting the things most essential —war material. Industrial needs had to wait. Now the country is catching up. Our stimulated productive capacity has been diverted from war to peace channels and a booming business still struggles to meet the demand made upon it. In Europe the conditions are similar but more acute. Industry was put out of joint there worse than here. It will take Europe longer to recover and readjust, meanwhile some of their immediate needs must be supplied from this side and this requirement puts an added demand on us and still further defers our return to a pre-war normal status. New nations have been created—financial and many other problems demand solution, all taking time and

yet more time, and keeping the United States still working extra hours. Although the supply of workmen has been greatly augmented by demobilization the peace demands have absorbed this supply and as yet there is no surplus. Many people say there never will be a surplus. That the United States has taken up a new place in the world's industries and henceforward will be expected to produce and will supply a so much larger share of the total world's commerce than ever before that our industries will be kept going at top speed and every workman be busy. This is certainly an optimistic picture. It is worth examining. Europe owes a lot of money. Some of their men have been killed. In the war zone the country was laid waste. These are the only real differences between then and now. Their abilities are no less, their natural resources are intact, their morale is good. Europe competed with us before the war and although we set up a tariff wall around our own country and successfully protected our domestic business she captured most of the world's trade against our best efforts. Of course we now have certain advanvantages we did not possess before. We are a creditor nation and can exert the influence attaching to that position. We have made tremendous inroads into Europe's foreign commerce while she was down and out commercially and we have thereby established relationships and gained an entree previously denied to us and which if judiciously followed up should produce results of great value. But the European nations are not out of the running permanently. They must recover a large volume of trade or go bankrupt. They are diligent and by nature and training thrifty. They will work under the spur of necessity. We are naturally spendthrifts. We are inclined to overconfidence. When the world's productive capacity shall have caught up with the industrial shortage occasioned by the great war and the demands of commerce shall have again become normal and when Europe's industries are once more functioning properly, it seems reasonably certain that there will be an excess of production over consumption and some nations will lack a market. Translated to workmen, this means that the supply will be greater than the demand and some must go hungry. It will be then that the test will come. If the United States shall have used the prosperous period to prepare for it by reducing the costs of production and by teaching its people economy and thrift the readjustment may come perhaps without any serious disturbances and we may save a good share of what we had gained by our running start. But if we sail serenely on ignoring the possibility of a coming storm, if we continue the policy of working less and less and of paying more amd more while Europe buckles to, the resulting depression with its period of unemployment, suffering and possible panics is appalling to contemplate. Then prices and wages will come down suddenly and with a thump—such a thump as the country has never known. The inexorable law of supply and demand is no respector of people or nations and its deadly work will be deadly indeed.

We now come back to the question I asked in the first place, "Can the engineer do anything about it except pay and grin?" I think he can. An engineer is by training taught to think straight and to speak clearly. Further it is a fixed tenet of his faith to tell the truth and fear none. People know that and believe him. If I have been fortunate enough to have made my views clear to you and if you agree with me, say so, and keep on saying it as you go about your daily tasks. Do what you can to show up the idiocy of dwelling in a fool's paradise and preach the gospel that industrial preparedness is as essential to commercial safety as military preparedness is to national safety. Dispel the bogy of class control. Brains always have ruled the world and brains always will. Show that we are dealing with a perfectly normal problem which must be solved in conformity to well-known natural laws and not with any mysterious unknown or novel principles or with newly discovered rules of life. No organization of a minority created for the avowed purpose to taking from the majority some of its property or just rights can long prevail. Witness organized Germany's effort to subjugate the world. The law of supply and demand will ultimately just as surely bring down the cost of living and the wages paid employees as it put the items up. The only uncertain features are the time when the changes are to occur and whether these costs and wages shall be brought down in an orderly and gradual manner so that the readjustment shall be made without disturbance and with lasting benefit to all or whether they shall come down with a thump, heard around the world, amid disaster and distress.

This is one of the most important problems confronting our great nation to-day. As citizens it concerns us all. As members of the A. I. E. E. who have enjoyed the privilege of special training and of valued association with our fellows we have each a duty to perform. It is perhaps as well stated as may be on the old familiar railroad crossing sign, "STOP, LOOK, LISTEN."

Changing 33-Cycle Apparatus To Operate on 60-Cycle Circuits

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BEFORE dealing with any of the specific problems involved in changing 33-cycle equipment to 60-cycle operation, it would be well to review a few historical facts which were responsible for the two frequencies now in use on the system of the Portland Railway, Light and Power Company of Portland, Oregon.

In a paper, read by Mr. F. G. Sykes before the Electrical Transmission Section of the Pacific Coast Engineering Congress held at the Lewis and Clark Centennial Exposition, June 29 and 30, 1905, are many references to the early development of the electrical industry in Portland. This article gives the following information: The first contract for city lighting was taken March 18, 1885, and at Weidler's Mill in North Portland a brick building was erected to house the boilers, engines and dynamos. In 1887 this plant was enlarged by the addition of five 750-light, 1000-volt Westinghouse alternators, with a frequency of 125 cycles. The following year, on November 8, 1888, the Willamette Falls Electric Company was incorporated, and all of the Weidler Mill equipment, except the original five Westinghouse alternators, was moved into Station A, Oregon City. In 1889 the equipment in the Willamette Falls power plant consisted of six Westinghouse 80-kw., 125-cycle, 4000-volt generators and two Thomson-Houston 120-kw. 125-cycle, 2000-volt generators and eleven 100-lamp, Excelsior arc machines, the lamps being rated at 2000 c. p. Each of these nineteen machines had its individual circuit into Portland, a distance of approximately fifteen miles.

The growth of the electric railway system in Portland in 1893 demanded a new order of things. Direct current in larger quantities was needed. The synchronous converter operating at frequencies in the neighborhood of 25 to 30 cycles had been successfully built at this time, and with the view to supplying direct current for railway service through the use of such apparatus and on account of that frequency being well adapted to the economic speed of the water wheels, the frequency of 33⅓ cycles was adopted when the new plant on the west side of the river at Oregon City was constructed. This frequency was also expected at that time to prove successful in the operation of a-c. arc lamps. Four sections of the Station B plant were built at that time and four 450-kw., 200-rev. per min., 33-cycle generators were installed with separate lines to Portland, two of which operated 400-kw. synchronous converters located in the basement of the office of the Portland General Electric Company at Seventh and Alder streets.

It was some years after this that there was a demand for 60-cycle service in Portland for light and power. This frequency was obtained by regeneration, using frequency changers. Two 500-kw. sets consisting of 33-cycle motors direct connected to 60-cycle generators were first installed and were followed later by several 1000-kw. sets.

The first direct generation of 60-cycle electric energy of importance was in the summer of 1908, following the disaster at the Cazadero hydroelectric plant of the Company. Since that time the 60-cycle load has gained so rapidly that nearly all of the generating and transforming equipment installed during recent years has been designed for 60-cycle operation.

On page 55, Volume 37, of the A. I. E. E. TRANSACTIONS will be found an article by Mr. B. G. Lamme entitled "The Technical Story of the Frequencies." He mentions a few of the frequencies that have been in use in this country such as 133⅓, 125, 83⅓ 66 ²/₃, 60, 50, 40, 33⅓, 30, 25 and 16²/₃. Several of these earlier frequencies were a result of convenient construction rather than of design. For instance, it was convenient to build a generator for a speed of 2000 rev. per min. and 8 poles. This gave 16,000 alternations per minute or 133⅓ cycles per second.

It had for a long time been recognized that the operation of the system with two different frequencies was disadvantageous. Sixty-cycle generators could not be used to operate 33-cycle motors or synchronous converters except through frequency changers with the consequent loss and the inflexibility due to location and size. Neither could 33-cycle generators be used to furnish the energy required by 60-cycle motors. Duplicate transmission lines had in some cases to be built where one might have served if there had been one frequency only, and there are many other reasons why a single frequency is desirable.

In the spring of 1918, due to the increase in load brought on by the war industries, the company was confronted with a situation where it was necessary to secure additional 60-cycle generating capacity. It had 33-cycle generating capacity rather in excess of the needs, but even though the frequency changers could be considered as available as 60-cycle generators,

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there was still need for additional 60-cycle current capacity to take care of the increases in the 60-cycle war industries load.

Mr. O. B. Coldwell, the company's General Superintendent, went East to determine what could be secured to meet the needs of the situation. As a result of the investigations made on this trip, it was decided to change the largest one of the company's generating units from 33 cycles to 60 cycles in a unique way.

The machine involved in the change was installed in 1912 and was a two-pole 7500-kw. 1980-rev. per min., 33-cycle, 5500-volt generator direct connected to a six-stage horizontal Curtis turbine The generator winding was star-connected, and was operated with grounded neutral. The station bus voltage of 11,000 was obtained by the use of a 2 to 1 ratio, three-phase 5114 kv-a. auto-transformer.

The method which was decided upon, of changing the generator from a 33- to a 60-cycle machine was to change the polarity of one of the two field poles, making both of the same polarity and causing two poles of opposite polarity to be induced at 90 deg. to the wound poles, and to reduce the speed of the machine from 1980 to 1800 rev. per min. The stator winding required changes in connections, but it was not found necessary to remove the winding from the slots. The two-circuit star-connected winding was changed to a single-circuit star-connected winding. It was also necessary to change the connections and ratio of the auto-transformer to provide for changing the generator voltage of 7000 to the bus voltage of 11,000. (Fig. 1.)

When the change to 60-cycles by inducing two poles was suggested, it was recognized by the manufacturing company's and operating company's engineers that poles would not only be induced at 90 deg. to the poles set up by the wound coils in a plane perpendicular to the axis of rotation, but that there would be a certain amount of endwise or axial flux, caused especially by the flux linkages with the end turns on the rotor. Therefore, it was suggested that compensating coils be placed at the ends of the rotor concentrically with the shaft in such a way as to oppose or counteract the endwise flux. The General Electric Company's engineers designed such compensating coils each to be composed of 66 turns of 0.1-in. by 2-in. flat ribbon copper mounted on the inside of the inner end shields. To check up the requisite number of ampere turns in the compensating coils, as well as to confirm the prac-

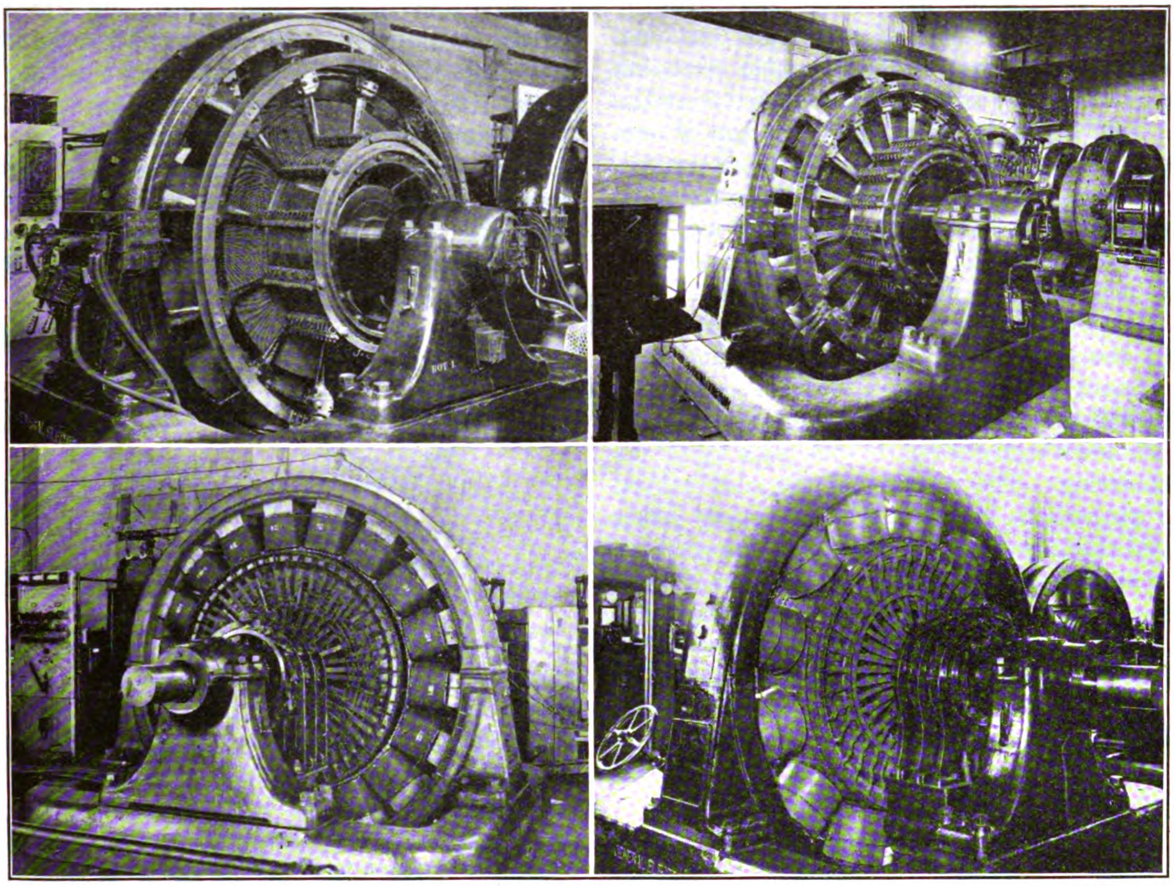

Fig. 1

Direct-Current End of Rotary Converter before Change

Direct-Current End of Rotary Converter after Change

Alternating-Current End of Rotary Converter after Change

Alternating-Current End of Rotary Converter before Change

ticability of the converted machine, the manufacturers made a test on a much smaller machine at the factory. They changed a two-pole machine of much the same characteristics as the 7500-kw. machine into a four-pole machine by inducing two new poles. The results of their tests were not available until after the change was actually made in the 7500-kw. unit at Portland, but they also demonstrated that the idea was practicable. It was found in the case of the test machine that the compensating coils were not needed, but this apparent result may have been due to the fact that the machine was not run long enough to develop trouble. In any event, as will be seen later, they certainly proved necessary in the case of the larger machine. The wave form in the case of the four-pole operation of the test machine was as would be expected from the field form, different in its two halves, the top of one-half being flat while the other half was more peaked, higher, and showed the steps caused by the rotor slots.

The change-over to 60 cycles on the 7500-kw. unit at Portland was started in July, 1918. The work was completed including the installation of the compensating coils. Considerable difficulty was encountered in securing the copper for these compensating coils and it was finally obtained from a manufacturing jeweler, who rolled the copper to size in lengths of about 20 feet and made it into one continuous piece by means of silver soldering. The winding of the coils proved a difficult process on account of the copper being drawn out of shape in the rolling. When the machine was started up and cut in as a 60-cycle machine, it operated satisfactorily for a couple of days, carrying loads up to 5000 kw., when troubles commenced. The fifth-stage runner in the steam turbine became loose on the shaft and shifted endwise, causing it to rub on the stationary vanes and necessitating the removal of the intermediates from this stage. After this was done and the machine started again, it developed an excessive vibration and the coupling between generator and turbine was trued up in an endeavor to improve the balance. This did not however remove the trouble and various other experiments were made to improve its operation, such as changing the turns and current in the compensating coils and lowering the stator to increase the air gap on the bottom, with the idea of compensating for the increased magnetic paths, due to the bed plate. None of these experiments however was instrumental in entirely removing the difficulties, and during the fall of 1918 when the generating capacity of every plant on the system was required to carry the imposed load, it was not possible to take the machine out of commission long enough to make a thorough investigation into the causes of the trouble, even though it was only possible to operate it at loads not exceeding 2500 kw. and although it vibrated excessively. However, as soon as the winter rains brought water to the hydraulic plants and the steam plants were relieved, the machine was given a thorough overhauling. It was and is appreciated that if the machine could have been overhauled as soon as the first troubles developed, a number of the repairs later necessary might have been avoided. The fifth-stage intermediates were restored and wheel shrouds repaired, the shaft was trued up, bearings rebabbitted and scraped, the field coils and compensating coils reinsulated and the machine put in first class condition. While the turbine was being overhauled, tests were made on the revolving field to see if poles were balanced. These tests revealed that some turns were short-circuited. It was found that the end turns had become distorted and the insulation had been cut on one of the straps connecting the bottom of one series of coils to the top of the next. Repairs were made by driving sheets of hard mica between the straps and the coils. The distortion of the coils was apparently caused by the action of centrifugal force because of insufficient wedging between coils. (See Fig. 2). This failure when discovered was considered entirely responsible for the vibration of the machine, but other difficulties were found later.

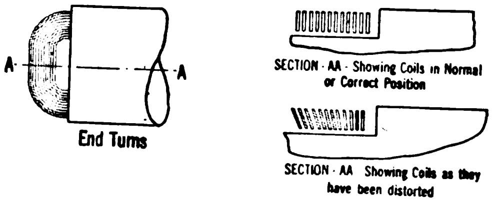

FIG. 2—SKETCH SHOWING FAILURE IN FIELD WINDING ON 7500-KW. TURBINE

The machine was carefully balanced and tried again, but after operating a short time with field circuit closed, it developed its former tendency to vibrate excessively. It was tried at first with no current in the compensating coils, inasmuch as the General Electric Company had not found it necessary in the case of the test machine. Then a separate machine was provided to supply current to the compensating coils and trials were made with various ratios of current in field coils to current in compensating coils. During some of these tests, it was discovered that the insulation between the outboard bearing pedestal and bed plate had broken down. This was repaired, and in trying out the mechanical balance, it was found the governor drive gear which was mounted on an end of the main shaft was not running exactly true and caused some unbalance. The end of the shaft was then ground in the bearings and the governor drive pinion bushed to fit by electrically welding on material and reboring. This improved the mechanical balance but the vibration reappeared when operated for any length of time with field circuit closed. An examination of the bearings showed that apparently electric action was taking place. During the investigation of the electric action in the bearings, a brush was placed on the shaft between the middle bearing and the rotor and electric-

ally connected to the bearing pedestal. Within a very short time after the field circuit was closed, the ½-in. bolt connecting the brush to pedestal melted off, showing that an enormous current was flowing, Following this, careful readings of voltage were taken between the shaft and pedestals on all bearings and from pedestal to bed plate on the insulated bearing, under various conditions. By varying the current in the field coils and compensating coils, it was found that it was possible to materially vary the voltages between shaft and bearing pedestals. The voltage readings were taken with a d-c. voltmeter and tests showed that there was practically no alternating voltage under any of the conditions. When the current in compensating coils was reversed and the resultant flux augmented instead of opposed the endwise flux from the field coils, the voltage between shaft and bearing pedestal was very materially increased. By experiment, it was found that with flux set up by current in the compensating coils opposing the endwise flux caused by excitation of the field poles, increases in current in compensating coils up to a certain point tended to decrease the bearing voltages, and any given

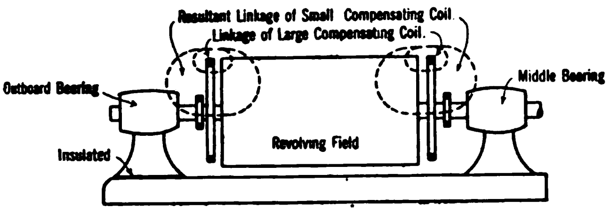

Fig. 3—Sketch Showing Magnetic Circuits of Compensating Coils

field excitation and increases beyond that reversed the bearing voltages.

It was apparent therefore that there might be a certain ratio of compensating coil current to field current which if maintained might keep the bearing voltages below an allowable maximum. This was found to be the case but the ratio was found to be so great that the required compensating-coil current corresponding to full-load field current was larger than the coils would carry continuously. It was further apparent that the compensating coils were not fully effective in doing that for which they were designed. A diagrammatic illustration of our conception of the flux linkages is shown by a sketch. (See Fig. 3). The bearings were acting as direct-current generators, because the shaft was cutting the magnetic lines of force which used the shaft and bearing pedestal as part of the magnetic circuit. The compensating coils as at first designed were evidently not sufficiently effective in opposing the flux in the shaft.

From a study of the theoretical considerations involved, it was thought that compensating coils closer to the shaft would be much more effective. Some experiments made with coils of cable wound on the outside of the inner shield indicated the correctness of the assumption and consequently additional coils were designed to be placed in series with the already installed coils, and to be located near the shaft. It was found to be difficult to find space in which to locate the coils, but by winding one of the coils in place on the machine, the other being wound in the shop, the desired 19-turn coils were constructed and installed on each end. The location of the coils is illustrated in a sketch. (See Fig. 4). All of the compensating coils are operated in series and in series with the field coils, thus main-

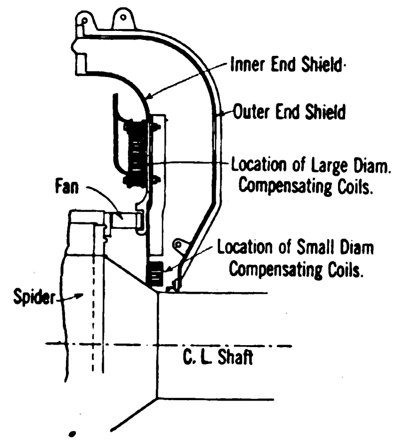

Fig. 4—Sketch Showing Details of End Shields and Compensating Coils on 7500-Kw. Turbo-Generator—Station E

taining proper ratio of ampere turns for all values of field current. The ratio was computed for unity power factor conditions, but it has been found that under any conditions of operation, the voltage on the center bearing where the effect is most marked does not exceed 1¼ to 1½ volts. The operation of the bearings has been entirely satisfactory since the current in the bearings has been reduced and no further vibration has occurred. The wave form as shown by an oscillogram was practically sinusoidal. (See Fig. 5).

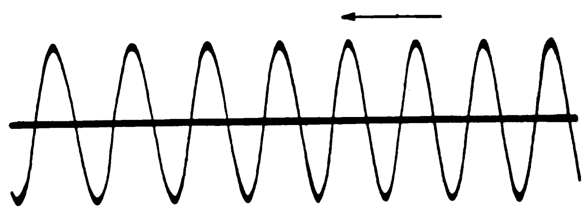

Fig. 5—Oscillogram, No. 5 Turbo-Generator—Station E—Generator, Open Circuit

As stated before, one of the reasons for the adoption of 33 cycles as a system frequency was in order that synchronous converters could be used, and a considerable number of these machines was purchased and installed to furnish railway service. When considering the problem of effecting economies through a reduction in the amount of 33-cycle apparatus, it was necessary to consider especially the 1000-kw. converters. It was not feasible to sell them and buy 60-cycle machines as there are very few systems on

which they could be used. Consequently Mr. Coldwell sought to solve the problem by changing the converters into 60-cycle machines. His preliminary analysis indicated to him that there was a chance of its being accomplished and he therefore had the matter gone into thoroughly. As a result a 1000-kw. converter has been converted from a 33-cycle to a 60-cycle machine by changing the number of poles from 12 to 18 and by increasing the speed from 333 to 400 rev. per min. The method of making the changes is described in the following:

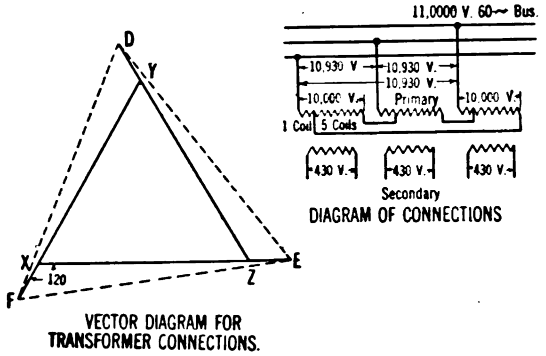

FIG. 6—THREE 10,000-VOLT AIR BLAST TRANSFORMERS CONNECTED TO OPERATE ON AN 11,000-VOLT BUS AND MAINTAIN NORMAL SECONDARY VOLTAGE

The synchronous converter under consideration in its original state was a 12-pole, 1000-kw., 333-rev. per min., 600-volt d-c., $33\frac{1}{3}$-cycle, six-phase machine. The armature core has 324 slots wound with two coils per slot making 648 coils. This number is not only a multiple of six (one-half the number of poles of the original machine) six, the number of phases, and 18, the number of coils per phase, but also a multiple of nine (one-half the number of poles of the new machine) six, the phases, and 12, the coils per phase. Changing from 12 poles at 33 cycles to 18 poles at 60 cycles increases the speed from 333 to 400 rev. per min., or an increase of 20 per cent. This was considered safe from a structural standpoint.

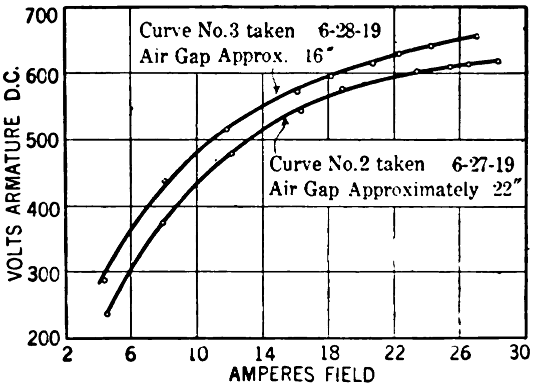

FIG. 7—SATURATION CURVES—60-CYCLE CONVERTER—SHOWING EFFECT OF CHANGE OF AIR GAP

The coils before the change occupied slots 1 and 26, etc., and in the rewinding were given a pitch such that they occupied slots 1 and 19, etc. It would be natural to expect an increase in flux density in the armature teeth, but the increase in speed prevented the flux from being as high as it would otherwise have been. The flux density in the armature teeth of the original machine at full load was about 138,000 lines per sq. in. and in the new machine about 180,000 lines.

The field poles, field windings and bridges for the changed over machine were designed and constructed by the General Electric Company, and the work of reconnecting the armature, changing the brush rigging, reassembling, etc., was done locally.

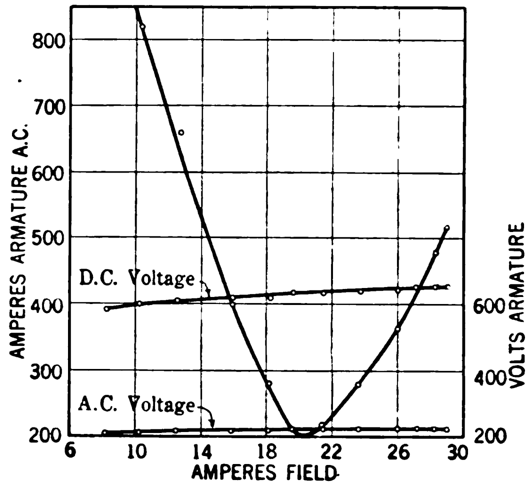

FIG. 8—PHASE CHARACTERISTIC CURVE—60-CYCLE CONVERTER

Work on rewinding the armature was started first. All the coils were taken off, cleaned, retaped where necessary and reshaped. The coils were put back in the slots with new slot insulation and new wedges, and reconnected with a pitch such that the coils occupied slots 1 and 19, etc. The connections from the collector rings would not conform to the new division of the coils, so six ring buses were secured to the spider on the a-c. end by means of fiber clamps and to these buses were soldered the connections from the collector rings and also those from the clips on the armature

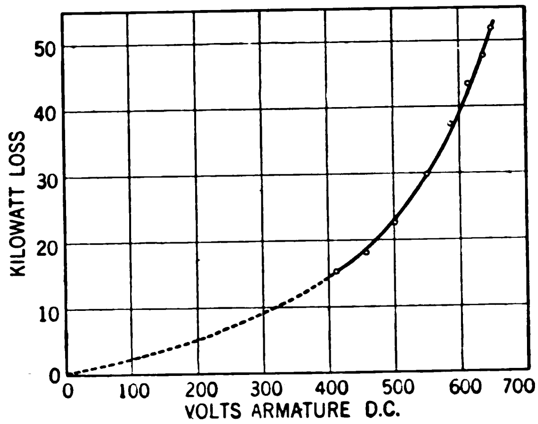

FIG. 9—OPEN-CIRCUIT CORE LOSS CURVE—60-CYCLE CONVERTER

windings, the connections, of course, being arranged in proper sequence. The final work on the armature was banding it with extra heavy banding wire.

The magnet frame was stripped of its original field poles and sent to a machine shop where it was bored out to a larger inside diameter and bolt holes drilled to receive the new pole pieces and field coils furnished by the manufacturers.

The brush holder ring was altered to support 18 brackets for brush studs instead of 12. This was accomplished by electrically welding two cast iron blocks on opposite sides of the ring, machining them to dimension and drilling. Extra brass brush holder brackets, studs and connection pieces were supplied to complete the d-c. brush rigging. After all the new and worked-over parts had been collected together, the assembling was accomplished with very little difficulty.

The air-blast transformers which form a part of the synchronous converter equipment have a voltage ratio of 10,000 to 430. The 60-cycle bus voltage is 11,000, so something had to be done in the way of

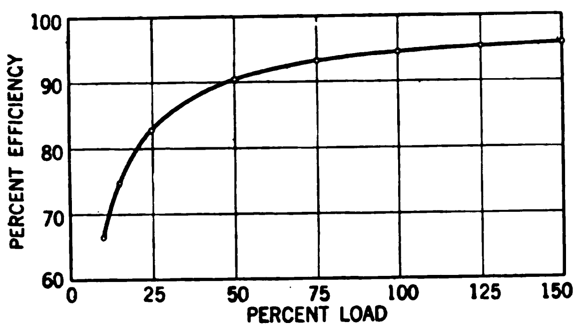

FIG. 10—LOAD-EFFICIENCY CURVE BASED ON AN ASSUMED RATING OF 1500 KW.

increasing the ratio between the primary and secondary in order to maintain normal voltage on the direct-current side of the converter. This was accomplished by a novel scheme of primary connections, shown in the accompanying sketch. (See Fig. 6.)

Testing of the newly assembled machine was the next step in the progress of the experiment. The first tests were the usual preliminary ones such as insulation tests on field and armature, cold resistance measurement of the field, drop on individual field coils and polarity test. Following these tests, a 60-h.p., 600-volt motor was belted to the converter shaft to drive it while under test. Saturation readings were first taken which showed that it was not possible to obtain a d-c. voltage in excess of 600 volts because of too great a reluctance in the magnetic circuit. Therefore, the air gap was reduced from 0.22 in. to 0.16 in. by inserting sheet iron shims between the poles and the magnet frame and another set of saturation readings taken. This change showed a very satisfactory improvement. (See Fig. 7). The converter was then started from the 60-cycle bus and brought up to speed. The brushes were adjusted for best commutation, and voltage readings taken on the a-c. and d-c. sides to determine the ratio of conversion. The ratio was about 71 per cent as was to be expected.

A phase characteristic test was made next and curves plotted. (See Fig. 8). The machine was then run without load and at unity power factor for ten hours and temperatures of the various parts taken. The inside of the field coils showed the hottest tempera-

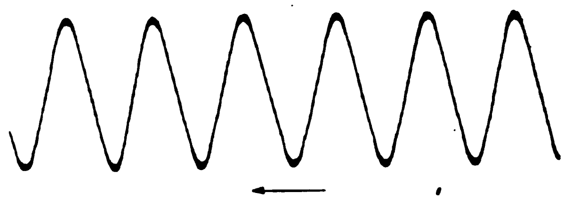

FIG. 11—OSCILLOGRAM, 60-CYCLE SYNCHRONIZED CONVERTER, REDUCED SPEED

ture to be only 64 deg. cent. It was next put in service on the railway bus and operated in the usual manner for several days. We then imposed a heavy load condition on it for eight hours, holding the power factor as nearly unity as possible and observed it closely. It remained comparatively cool and its commutation was excellent, notwithstanding the current varied from 1000 to 3000 amperes.

Determination of new rating and efficiency demanded a core loss test. (See Fig. 9). From this and the foregoing tests efficiencies were calculated on a basis of 1500 kilowatts as normal load. (See Fig. 10). A load of 1500 kilowatts was then held on the converter until constant temperatures were reached, then shut down and temperatures of all parts taken. The temperature in degrees centigrade of hottest spots were: field by rise in resistance calculation 61.5 deg., pole tips 56.5 deg., armature core 51.5 deg., air duct 54 deg., field coil inside 55 deg., and commutator 49.5 deg. The room temperature was 24 deg. cent. These temperatures were by no means excessive and it was concluded that the external wiring and transformers, rather than the internal heating of the converter, precluded a safe loading beyond 1500 kilowatts. Finally an oscillogram was taken of the voltage wave with the machine running as a generator separately excited from the railway bus. (See Fig. 11).

NATIONAL ELECTRICAL CODE

The Electrical Committee of the National Fire Protection Association will hold public hearings on the items appearing in its bulletin on March 23 and 24 in the Assembly room of the New York Board of Fire Underwriters, 123 William St., New York. Any member of the Association interested in electrical fire hazards is welcome at these hearings, and is privileged to speak. For copies of bulletin apply to Secretary Ralph Sweetland, 141 Milk St., Boston, Mass.

Mutual Inductance of Two Straight Cylindrical Conductors Which Lie in Parallel Planes but which are not themselves Parallel

BY ALBERT M. JACOBS

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CONSIDER a symmetrical arrangement, *i. e.* supposing the planes containing the conductors to be horizontal then the horizontal projections of the conductors shall bisect each other.

It is assumed that the total length of conductor to be considered is contained between two parallel planes cutting one of the conductors at right angles.

That is, the field due to the current flowing outside of the length of conductor under consideration is assumed to have no effect on the conductors, *e. g.* if a generator be connected to one end and a motor to the other.

Let the vertical distance between conductors be s and the horizontal distance between conductors, measured in the end planes, be r. The maximum distance between leads is then $\sqrt{r^2 + s^2}$.

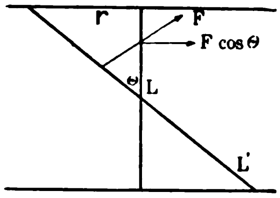

FIG. 1

Let the angle included between the horizontal projections of the leads be θ. Consider the action of the longer lead (of length L') on the shorter lead of length L. The component of the field F, due to L', which cuts L at right angles is $F \cos \theta$. The total field being proportional to L', the component cutting L at right angle is proportional to $L' \cos \theta$ *i. e.* proportional to L.

In the expression for M *viz.* $2L\left(lgn \frac{2L}{d} - 1\right)$ we may therefore use L instead of $L' \cos \theta$.

As d varies from point to point, the average value of $lgn \frac{2L}{d}$ has to be found. Taking the point of intersection of the horizontal projections as the origin, O, and the direction of the shorter lead as the abscissa axis, the ordinates will represent the horizontal distances between leads from point to point. The vertical distance being constant throughout, d may be expressed as the hypotenuse of a right-angled triangle.

The expression for $lgn \frac{2L}{d}$ is to be integrated between the limits O and $L/2$, the definite integral multiplied by 2 and the result divided by L to obtain the average value sought.

Let x = distance along shorter lead measured from O.
y = ordinate corresponding to x.
Then y is obviously proportional to x, *i. e.* $y = cx$

When $x = L/2$, $y = r$, whence $c = \frac{2r}{L}$

$$y = \left(\frac{2r}{L}\right) x.$$

Therefore $d = \sqrt{y^2 + s^2} = \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2}$.

$$\text{and} \int_0^{l/2} lgn \frac{2L}{d}\, dx$$

$$= \int_0^{l/2} lgn \frac{2L}{\sqrt{\left(\frac{2r}{L}\right) x^2 + s^2}}\, dx$$

$$= \int_0^{l/2} lgn\ 2L\, dx$$

$$- \int_0^{l/2} lgn \sqrt{\left(\frac{2r}{L}\right) x^2 + s^2\, dx} \qquad \textbf{(A)}$$

Consider the second integral. Omitting limits pro tem we may write it as:

$$\int \frac{d}{dx}(x)\, lgn \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2\, dx}; \quad \text{and}$$

integrating by parts this is equal to:

$$x\, lgn \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2}$$

$$- \int x \frac{d}{dx} lgn \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2}\, dx. \qquad \textbf{(B)}$$

Differentiating and multiplying by x we obtain finally $\frac{x^2}{\left(x^2 + \frac{s^2 L^2}{4r^2}\right)}$. Throwing this into partial fraction form we obtain:

$$\frac{1 - \frac{s^2 L^2}{4r^2}}{\left(x^2 + \frac{s^2 L^2}{4r^2}\right)}$$ in which form the integral may readily be written as:

$$x - \frac{SL}{2r} \tan^{-1} x \left(\frac{2r}{sL}\right).$$

(B) then becomes:

$$x\, lgn \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2}$$

$$- x + \frac{sL}{2r} \tan^{-1} x \left(\frac{2r}{sL}\right)$$

and **(A)** becomes, omitting limits,

$$x\, lgn\, 2L - x\, lgn \sqrt{\left(\frac{2r}{L}\right)^2 x^2 + s^2}$$

$$+ x - \frac{sL}{2r} \tan^{-1} x \left(\frac{2r}{sL}\right).$$

which may also be written

$$x\left(l\,g\,n\sqrt{\frac{2\,L}{\left(\frac{2\,r}{L}\right)^2 x^2 + s^2 + 1}}\right.$$

$$\left. - \frac{s\,L}{2\,r}\tan^{-1} x\left(\frac{2\,r}{s\,L}\right)\right)$$

For the lower limit, $x = 0$, this expression vanishes. Inserting the upper limit, $x = L/2$, and multiplying by $2/L$ we obtain:

$$l\,g\,n\sqrt{\frac{2\,L}{r^2 + s^2}} + 1 - s/r\tan^{-1} r/s.$$

which is the *average* value of $l\,g\,n\,\frac{2\,L}{d}$.

Inserting this value in the expression for M we obtain

$$M = 2\,L\left(l\,g\,n\,\frac{2\,L}{d_{max}} - s/r\tan^{-1} r/s\right).$$

The last term in this expression may be somewhat differently expressed. In the containing planes at the ends of the conductors the latter would appear as in diagram at side.

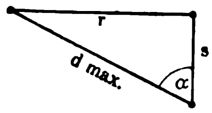

Fig 2

Now $s/r = \cot\alpha$
and $\tan^{-1} r/s = \alpha$
M may then be written:

$$2\,L\left(l\,g\,n\,\frac{2\,L}{d_{max}} - \alpha\cot\alpha\right).$$

If the arrangement be unsymmetrical *i. e.* if the projections of the conductors on a horizontal plane do not bisect each other the above method can obviously still be used by integrating between the correct limits.

For parallel conductors, r vanishes and α becomes zero. It may readily be shown that the limiting value of $\alpha\cot\alpha$ is unity, and the expression for M reduces to the standard value.

For conductors cutting each other at right angles r becomes infinite and M becomes zero.

The aim of this investigation was to develop an expression which could readily be used in practical layouts in which the values of r and s would be readily obtainable, rather than to obtain a general mathematical expression depending on the lengths of leads and the angle θ contained between the horizontal projections.

The value found for M is the average M of an infinite number of conductors running parallel to the shorter one and at all horizontal spacings between zero and r. The longer conductor may be considered as replaced by a conductor running parallel with the shorter one at a distance D which may be found from the equation:

$$l\,g\,n\,\frac{2\,L}{d_{max}} - \alpha\cot\alpha = l\,g\,n\,\frac{2\,L}{D} - 1$$

from which it follows that $D = d_{max}\,e^{\alpha\cot\alpha - 1}$

Constant Potential Series Lighting

BY CHAS. P. STEINMETZ
Chief Cons. Engr., General Electric Co.; Prof. Electrophysics, Union College, Schenectady, N. Y.

UNTIL recent years, street lighting in the United States has been almost exclusively by the high-voltage constant-current series system, either direct current or alternating current, and low-voltage constant-potential multiple systems have been used to a very limited extent only. This was for two reasons, one social-political, the other electrical.

To the democratic character of the country, only such form of lighting appeared suitable, as was applicable alike to the scattered suburbs and to the more densely populated center of the city. Thus high voltage had to be used, either a series system, or alternating current with individual transformers. The latter was excluded at first by the absence of a satisfactory alternating-current arc lamp and by the high cost and low efficiency of the small individual transformers. Thus American street lighting developed on the high-voltage series system, and much later only, with the gradual growth of civic pride of the city population, special lighting features were developed such as "White Way Lighting." The alternating-current arc lamp largely replaced the direct-current arc lamp; the small transformers became more efficient and less expensive; but still more efficient and economical was the constant-current transformers operating a whole circuit of alternating arc lamps, so that the conditions which led to the use of the high-voltage series system did not materially change.

The other reason was the electrical characteristic of the arc, which was the only illuminant of sufficient intensity and efficiency for street lighting. The arc is unsteady on constant potential, and requires a constant current or at least a circuit in which the voltage drops greatly with the increase of current. Thus, to operate an arc lamp on constant-voltage supply, a large series resistance or reactance is necessary, which makes it inefficient and, with alternating current, greatly lowers the power factor, and even then, the light is not as steady as when operating on a constant-current circuit.

As seen, of these two conditions, the first one requires high voltage, whether constant potential or constant

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current; the second one required constant current, which economically means series connection and high voltage. The first one still applies with practically the same force as before, but the second one has entirely changed, and thus makes a reconsideration and revision of our views on street lighting desirable.

With the exception of the luminous arc, which by its high efficiency and superior quality of light—perfect whiteness—holds its own, especially in high intensity and decorative lighting, such as "white way lighting," exposition lighting, etc., the arc lamp has practically disappeared from street lighting, and the gas-filled mazda lamp taken its place. With the disappearance of the arc lamp however, disappeared the necessity of the constant-current circuit. As an incandescent lamp, the gas-filled mazda lamp is a dead resistance, equally stable on constant potential as on constant current, and while the necessity of using high voltage still remains—especially in American cities, which as a rule cover a far larger territory with their street-lighting districts, than European cities of the same population—the need of converting from constant potential to constant current has ceased, and the high-voltage constant-potential street-lighting systems with gas-filled mazda lamps, thus have become possible and are increasing in frequency, either as high-voltage constant-potential series systems, or as high-voltage alternating-current multiple systems with individual transformers.

Unlike the carbon-filament incandescent lamp of old, which has a negative temperature coefficient of resistance, the metal-filament mazda lamp has a positive temperature coefficient, that is with a change of circuit conditions, in the mazda lamp the voltage varies more than the current, while in the carbon-filament lamp the current varied more than the voltage. Therefore, in a constant-potential circuit, the mazda lamp,—other things being equal—will have a better life than in a constant-current circuit having the same percentage fluctuation of current, as the constant-potential circuit has fluctuations of voltage, while the reverse was the case with the old carbon-filament lamp. Constant potential thus is somewhat preferable for the mazda lamp, that is to give the same life of the mazda lamp, the regulation of the constant-current system must be closer than that of the constant-potential system.

The regulation of the available constant-current systems, such as giving by the moving-coil constant-current transformer, reactor or similar devices, is amply close for the successful operation of mazda lamps. It is true that the incandescent lamp is much more sensitive to current variations than the arc lamp was, and while arc lamps are not affected by momentary current variations of 50 to 100 per cent, such as may occur in case of a surging of the circuit due to instability of the arc lamps, swinging grounds, etc., such current variations may be disastrous to the incandescent lamp.

However, in the constant-current mazda lamp circuit if reasonable care is taken of the insulation, the danger of surging hardly exists, and it is only where mazda lamps are operated in series with arc lamps, and the circuit is overloaded and the arc lamps allowed to get out of proper adjustment, that an impairment of the life of the mazda lamp, due to current surges, may occur.

As regards the regulation of constant-potential street-lighting systems, whether high-voltage series, or multiple systems with individual transformers, the problem of regulation of the voltage supply is eliminated by the fact that domestic lighting constitutes a large part of the load of the electric supply system, and the voltage regulation satisfactory for domestic lighting is equally satisfactory for constant-potential—series or multiple—street lighting. That is, constant-potential street lighting is operated from the same supply circuits and in the same manner as domestic lighting is.

Necessary in all series systems is a shunt protective device, that is, a device keeping the circuit closed in case one of the lamps open-circuits. Otherwise either all the lamps would go out or, if the circuit voltage is high enough, arcing occurs and causes more or less damage. The simplest form of shunt protective device is the film cut-out, used very largely in constant-current incandescent lamp circuits. Usually however, one of two other functions are combined with the shunt protective device; to restore automatically operation and to maintain the regulation of the circuit. In incandescent lamp circuits, the former is not necessary, as an open circuiting of the lamp means a burn-out, the lamp then has to be replaced, and when doing so, the film cut-out is renewed. In arc lamps however, the arc not infrequently breaks momentarily, and if then the film cut-out short-circuited the lamp, it would be put out of service. Therefore, in arc circuits, as a part of the arc lamp, a shunt magnet is used closing the circuit through a starting resistance, the latter giving sufficient voltage drop to allow the arc to start again when the electrodes come together.

In constant-potential series circuits, the operation of the film cut-out would reduce the circuit resistance, thereby increase the circuit current and impair the regulation and the life of the lamps. Thus the shunt protective device when operating, must insert a resistance or reactance into the circuit, such as maintains the total circuit impedance unchanged. For this purpose, the same device may be used as in arc lamps, that is, shunt magnet and starting resistance, making the latter equal to the lamp resistance. Such is used in the series operation of a number of arc lamps in direct-current circuits. Or a reactance may be used instead of the resistance, as in the series operation of two flame carbon arc lamps on constant-potential 110-volt circuits.

The objection to this device is the use of moving parts and contacts, and as series incandescent circuits are almost invariably alternating, as shunt protective

device maintaining the circuit regulation, a shunted reactance is used, which remains continuously in circuit, and when the lamp is in normal operation, by-paths only a negligible current, operating below saturation; but when the lamp burns out, the shunt reactance magnetically saturates and thereby drops in reactance to the value required to maintain the regulation. A constant shunt reactance cannot give regulation, since with the lamp burned out, but all other parts of the circuit the same, the total circuit impedance necessarily is higher, thus the circuit current lower, and the reactance in this case thus must decrease, to maintain the same circuit impedance. However, with the lamp burned out, the voltage drop across the shunt reactance is much higher than with the lamp in operation, since in the former case, the reactance voltage combines in approximate quadrature with the remaining circuit voltage.

The requirements of such a regulating shunt reactance thus are: (1) with the lamp in operation, to consume as little current and power as possible. (2) When the lamp opens, to drop by saturation to such a value of reactance as to give the same total circuit impedance as before, and thus maintain the circuit regulation. (3) To maintain the circuit regulation over as wide a range as possible, up to at least 10 to 20 per cent of burned-out lamps, so as to give ample time for renewal. These requirements can be fulfilled by proper design in a very perfect manner.[1]

Such shunt reactance may be, and usually is combined with other features. It may be used as an auto-transformer, so as to operate lamps of different current consumption in the same circuit or to operate a larger number of lamps in one circuit, without excessive voltage, by having the circuit current larger than the lamp current. Or it may be used as a transformer, with sufficient insulation between primary and secondary so as to make the secondary, that is, the lamp, a safe low-voltage circuit, especially when locating the transformer away from the lamp, and grounding it. However, in this case care must be taken in the design of the transformer to guard against dangerous peak voltage. Assuming a 6.6-ampere 300-watt lamp. The normal lamp voltage, and thus transformer secondary voltage, then is 45.5 volts. At open circuit, that is, with the lamp burned out, the secondary voltage then would be of the magnitude of 100 volts effective. However, the voltage wave may be very greatly distorted by saturation, having high voltage peaks—at the moment of magnetic reversal—reaching into dangerous values.

The foremost disadvantage of the constant-potential series system is its lesser flexibility. From a constant-current transformer any number of lamps can be operated, with equally good regulation, from full load down to a fraction of it—though it is economically undesirable to operate a constant-current transformer much below full load, as with decreasing load, the power factor rapidly decreases. In a constant-potential series system, however, the number of lamps is given by the circuit voltage. Thus from a 2300-volt constant-potential supply could be operated $\frac{2300}{45} = 51$. 300-watt 45-volt lamps, neither more nor less. This limitation is overcome by the use of transformer taps and idle regulating reactors. Thus considering a 100-lamp circuit, operated from an ordinary constant-potential transformer with 4500-volt secondary; giving the transformer secondary one 4 per cent and two 8 per cent taps, and using up to 3 idle reactors in series to the circuit, would give a 20 per cent range of load, which probably would be sufficient for most purposes.

A further disadvantage of the constant-potential system is its sensitivity to grounds. If two dead grounds occur in the same circuit, and thereby short-circuit a part of the circuit, the current in the remaining part of the circuit is increased, and if the short-circuited part of the circuit is considerable, all the lamps in the remaining part of the circuit may be burned out. How serious this is, depends on the quality of the circuit. However, with any reasonably well built and operated circuit, the probability of two dead grounds in the same circuit should be so remote as hardly to require much consideration.

On the other hand the great advantage of the constant-potential series system is its high power factor, of 95 to 99 per cent, the better efficiency, and especially, that it requires no station apparatus such as constant-current transformers, but can, and would be operated from a transformer on a pole in the distribution system, just like domestic lighting, and the mass of lines or cables running back to the stations, which are characteristic of the usual constant-current systems, due to the limited power per circuit, thus is eliminated.

In such constant-potential series lighting system, all the street-lighting circuits may be operated from one single feeder or a few feeders, which are connected or disconnected from the station at the proper time. While an advantage over the use of a separate feeder from the station for each street-lighting circuit, this is not as simple and convenient as connecting the constant-potential transformers on the poles in the street-lighting districts, which operate the street lighting, to the domestic-lighting feeders in their respective territory. This latter however requires some means of connecting and disconnecting the street-lighting transformers at the proper time of starting or stopping the street lights, since the domestic-lighting feeders are continuously alive.

Such may be done by manual operation of the switches, though such is rarely satisfactory.

Or it may be done by cascade operation, that is,

[1] Regarding the mathematics hereof, see "Theory and Calculations of Electric Circuits." Chapter XV.

having the street-lighting circuits overlap, and each start the next one, the first being started from the station. This may introduce some complications and limitations of the location of the transformers, and has the disadvantage that, if one switch fails, all the circuits beyond it are out of service.

Or time switches may be used, that is, switches operated by a clock located on the pole at the transformer. Such clocks however, exposed to weather, are not always as reliable as desirable.

Or a pilot circuit may be used, that is, a low-voltage direct-current circuit carried to all the switches. This means an additional circuit.

Another method, which in many cases is very promising, is the use of the phantom switch, that is, a switch operated with direct current by a polarized relay, so that one direction of the direct current closes it, the opposite direction opens it, with the direct current sent to the switch over a phantom circuit, such as are extensively used in telephony. That is, a direct current is sent through a balanced reactance in the station, into the neutral of the alternating-current distribution system, and at the switch passes from the alternating neutral through another balanced reactance to the relay which operates the switch. Such arrangement permits electrical long-distance operation without any additional circuit. It is not applicable in circuits with grounded neutral. However, in primary distribution circuits a grounded neutral is hardly ever used.

Comparing then the three types of high-voltage street-lighting systems; the constant-current series system, the constant-potential series system, and the constant-potential multiple system:

	I Constant-current series system	II Constant-potential series system	III Constant-potential multiple system
(1) Type of lamp.	Arc lamp or incandescent lamp.	Incandescent lamps only.	Incandescent lamps only.
(2) Station apparatus.	Constant-current transformer or reactor, etc.	No station apparatus.	No station apparatus.
(3) Number of station circuits.	A separate circuit for every lighting circuit.	No special circuits from station.	No special circuits from station.
(4) Number of wires per circuit.	Single-wire circuit.	Single-wire circuit.	Two-wire circuit.
(5) Accessories at lamp.	Film cut-out, or auto-transformer or series transformer.	Auto - transformer or series transformer.	Constant-potential transformer.
(6) Size of circuits.	Limited number of lamps per circuit.	Limited number of lamps per circuit.	Unlimited number of lamps per circuit.
(7) Flexibility.	Great flexibility in number of lamps.	Lesser flexibility.	Great flexibility in number of lamps.
(8) Power factor.	80 to 85 per cent with incandescent lamps. 70 to 75 per cent with arc lamps.	95 to 99 per cent.	Practically unity.
(9) Safety.	High voltage at lamp except when using transformer.	High voltage at lamp except when using transformer.	Low voltage at lamp.

Notes

(2) For I, constant-current pole transformers have been designed, without moving parts, and are in successful use to some extent, especially for smaller circuits; but usually are either lower in power factor or inferior in regulation.

Theoretically, II may be operated directly from the primary distribution feeders, but usually it will be preferable to interpose a constant-potential transformers on a pole in the lighting district, so as to reduce the trouble from grounds.

(3) In II or III, provision must however be made for starting and stopping the circuit, as discussed in the preceding.

(5) The film cut-out, as the simplest shunt protective device, is applicable only in I.

To secure low voltages at the lamp, so as to make it safe even when the circuit is alive, requires transformers in I as well as II. However, these transformers are series transformers, that is, with a moderate number of primary turns, while in III, the transformer has to step down from the total circuit voltage to the lamp voltage, requiring many turns of fine wire in the primary, and thus is more expensive to build and insulate.

In III, several lamps may be operated from the same transformer, if near together, but this then means a two-wire secondary circuit in addition to the primary circuit. The same could also be done in I or II.

(6) Both series circuits are limited in the number of lamps per circuit, but this limitation, while serious in a constant-current circuit which has to go back to the station, is of no moment in the constant-potential circuit, as the latter does not need to run back to the station but is fed from the transformer on the pole in the lighting district, and such transformer is of sufficient size to be efficient and economical.

The Alternating-Current Commutator Motor

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The alternating-current commutator motor in its various forms has been developed principally for the purpose of obtaining adjustable or variable speeds, the usual induction type motor, both in the single-phase and polyphase forms, being inherently constant speed. In general, control of speed with the alternating-current induction motor implies variable or adjustable frequency in some form, and this, in turn, involves a commutator of some type. In consequence, the problem of commutating alternating current usually goes hand in hand with that of speed control.

The simplest method, according to the author, for viewing both the a-c. and the d-c. commutating problems, is to consider primarily the actual e.m.fs. short-circuited by the brushes, and the resistance in the short-circuited paths,—or in other words, the problem of commutation is largely one of the permissible amount of short-circuited current. In the d-c. machine the e.m.f. short-circuited by the brushes is that generated by rotation of the short-circuited armature coils in the armature and external field fluxes. In the same way, in the a-c. commutator motor, there is an e.m.f. due to the armature flux or field, as in the d-c. machine, and in addition, there are other e.m.fs. due to the primary or field fluxes. These latter may be classified as primary rotational and transformer e.m.fs. One limitation in the design of a-c. commutator motors, in general, is that these rotational and transformer e.m.fs. are often larger in degree than the e.m.f. due to the armature flux. However, the author contends that the commutation problem in a-c. motors is the same as for d. c. when all e.m.fs. are taken into account.

The major part of the paper covers the consideration of the different e.m.fs. which should be taken into account in the various types of a-c. commutator motors, and it is shown in a general way that the e.m.fs. involved in speed control also appear in the commutation problem. In the latter part of the paper certain general conditions of commutation and brush operation are treated and some figures are given for comparison of a-c. and d-c. commutating limits.

THE alternating-current commutator motor in some form is doubtless the earliest of all alternating-current motors. Probably everyone of the old-timers who dabbled in alternating currents tried his hand, sooner or later, at this type of machine. Some even went so far as to put such motors on the market. Series-wound, shunt-wound, repulsion types, induction types, as they were formerly named, all had their trial, either experimentally or commercially, and all the early motors withdrew for one common reason; namely, sparking at the commutator. It must be kept in mind that all the earlier frequencies were quite high and it was recognized, early in the game, that this was a most serious handicap to successful commutation. One principal reason why the Niagara Falls Power Commission in 1892 chose 2000 alternations per minute (16 $^2/_3$ cycles per second) as its preferred frequency, was that commutator-type a-c. motors would thus be feasible for general power work.

In consequence of the commutation difficulties with all the early a-c. commutator motors, and their consequent withdrawal from the commercial field, the belief became most firmly established that alternating currents, in general, could not be commutated successfully and that it was hopeless to attempt further work on the problem.

This fallacy was the direct outcome of lack of knowledge of the general problem of commutation itself. The alternating current simply introduced additional conditions, all of which made the whole subject more complex and difficult to understand. In fact, in this early period, in most cases, the methods of treating the direct-current commutation problem were more or less incomprehensible and there was little or no physical conception of what was really taking place.

With clearer and better conceptions of the commutation problem, it began to be seen, by a few, that alternating-current commutation was quite closely related to that of direct-current; in fact, if all the conditions were included, it was evidently the same problem except in degree.

However, in one vital feature, the commutation in a-c. machines has been assumed to be fundamentally different from the d-c. In the former, the condition in many cases is largely that of short-circuiting part of the armature winding, by the brushes, under a magnetic field, or when enclosing an alternating magnetic flux. Superficially, this problem appears to be quite different from that of simply reversing the current in those armature turns lying midway between poles, as in the usual d-c. machines. This short-circuiting under a magnetic field (or enclosing an alternating flux) was supposed to introduce new and most intricate phenomena, and, apparently, the action was such that good, or even passable, commutation was not even theoretically possible.

As the theories and practises in d-c. commutation developed, new ideas began to grow and new viewpoints were obtained, which had a direct bearing on the corresponding a-c. problem. It was perceived, perhaps dimly at first, that the d-c. problem could be considered simply as a case of the brushes short-circuiting part of the armature winding in a magnetic field, such field being set up by the armature winding as a whole, or by a combination of armature and field fluxes. From such a viewpoint the problems of a-c. and d-c. commutation began to approach each other, and it was perceived that it was largely a matter of the values of the e. m. f. short-circuited, rather than the nature of the current itself.

Others may have anticipated the writer in this method of looking at the commutation problem, but

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possibly he was the first to go fully into the analysis of this method and to show its equivalence to former methods.[1] He found that this way of viewing the problem was of very great help in the consideration of a-c. commutating machines, both polyphase and single-phase. It put the short-circuiting and commutation problems on a comprehensible basis and at once eliminated from the treatment a large number of intermediate phenomena.

To express this method in its simplest form,—if a given e. m. f. at the commutator is short-circuited, with a given brush, similar commutating conditions are obtained, whether the current is alternating or direct. But *all* the e. m. fs. must be taken into account, and here has been the principal source of trouble, both in a-c. and d-c., but more in the former than in the latter.

In accordance with this method of treating the problem, the function of commutating poles, or their equivalent, is simply to reduce the short-circuited e. m. f. under the brush to a value within the resistance limits of the brush, as fixed principally by the brush contact and by any additional resistance in the winding which may be inserted for commutation. With the d-c. machine, this has been quite easy, as both the e. m. fs., due to the armature flux and due to the commutating pole, are proportional to the speed, and therefore, if properly set for one speed, the conditions hold for all speeds. But in the a-c. motor some components of the e. m. f. short-circuited by the brush are not a function of the speed, while others are, and thus the problem of a correct commutating field for a wide range of speed becomes a very complex one. The difficulty is inherently one of design, rather than one of theory or principle.

Narrowed down to its simplest form, in the d-c. machine, the commutation is dependent upon the e. m. f. short-circuited by the brush, and the permissible short circuit or local current. The permissible work current enters directly as one of the elements which determines the short-circuited e. m. f. The amount of short-circuit current permissible is dependent largely upon the characteristics of the brush and brush contacts. The amount of short-circuit current which can flow is dependent upon the e.m. f. short-circuited, and the conditions of the short-circuited path. Due to the characteristics of commercial carbon brushes, there are fairly definite limits to the e. m. f., which can be short-circuited while keeping the short-circuit current within the limitations of the brush itself as fixed by burning, disintegration, etc.[2]

In the a-c. machine quite similar limits hold, except that the short-circuited e. m. f. is partly, or in most cases largely, due to fluxes other than those resulting from the armature m. m. f. as in d-c. machines. In consequence, on the d-c. conditions are superposed additional ones, which often are more difficult than those corresponding to the d-c. However, the whole problem turns on the total short-circuited e. m. f. and the means for limiting the circulating or local current.

So much for commutation. Now as to the reasons for the use of commutator motors, when induction motors, both polyphase and single-phase, have been available. It has been well known, almost since the induction motor first appeared, that this type of machine has inherently constant speed characteristics. With the growth of the art and increase in the field for electric motors, there has come a demand for variable and adjustable speed alternating-current motors. The true induction motor cannot in itself give the variable speed characteristics of the series d-c. motor, nor the adjustable speed characteristics of the shunt machine. True, variations in speed with the polyphase induction motor are obtainable by means of resistance in the secondary circuit, but such speed regulation is directly comparable with the use of armature resistance in d-c. shunt motors and this characteristic is not a desirable one except for certain very limited uses.

The problem of true speed control in the induction motor is complicated by the fact that with change in speed, both the secondary voltage and the secondary frequency are directly related to the speed changes. It has been known for many years that, by the addition of suitable voltages in the secondary circuit of the ordinary polyphase induction motor, the speed could be controlled over any desired range, without rheostatic loss, but for each change of speed the regulating voltage supplied to the secondary winding requires a different frequency, and the difficulty in the past (as well as at present) has been to obtain the required special frequency for each speed. It is true that a very limited number of speed changes is possible by means of pole changing and by cascade connection of motors, but these give no true flexibility in speed adjustment. Up to the present, the only really flexible means for obtaining variable frequency for such motors has been through some form of a-c. commutating device, such as a multi-bar commutator connected to the secondary or the primary winding; or a commutator-type frequency changer, a synchronous converter, or a polyphase commutator-type motor, structurally independent, but connected to the primary or secondary circuits of the induction motor. It may be noted that the synchronous converter, transforming from alternating to direct current, is here included among the frequency-changer devices. This should be considered as a frequency changer when used in this manner, converting from direct current (zero frequency) to any a-c. frequency depending upon the adjustments. This implies direct-current circuits in addition to the alternating-current supply circuits. However, many of the

1. *A Theory of Commutation and its Application to Interpole Machines*, TRANS., A. I. E. E., 1912.

2. See *Physical Limitations in D-C. Machines*—TRANS., A. I. E. E., Sept., 1915.

other devices proposed imply transformation from the primary or supply frequency to some other frequency or range of frequencies, or vice versa. The commutator thus enters as a frequency-changing, rather than a current-rectifying device.

The Polyphase Commutator Type Induction Motor

Although the polyphase motor without commutator is a well understood device, yet there are various ways of treating its characteristics with regard to speed variations, etc. Some of these methods serve better for illustration than others. The following treatment, which has been used extensively by Eichberg, McAllister and others, probably gives the best visual conception of what takes place in such machines, in regard to the component voltages upon which commutation and speed regulation depend. The writer has accordingly adopted this for purposes of easy illustration, in connection with the several types of apparatus which are considered.

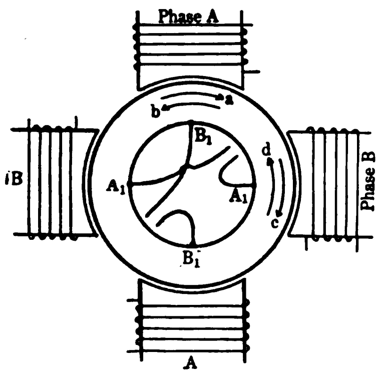

Fig. 1

Assume as the first and simplest case, a two-phase induction motor, in which the primary is illustrated as a two-pole construction with two sets of poles at right angles to each other, as shown in Fig. 1, and with a secondary of a ring type with four taps at A_1A_1 and B_1B_1 for two-phase connection. The e. m. f. relations in the secondary winding may be explained as follows:

Considering the rotational e. m. fs. first, the alternating flux from pole or phase A through the secondary will generate an e. m. f. a, as indicated in Fig. 1. Also the alternating flux from pole or phase B will generate in the winding a rotational e. m. f. c, as shown. These e. m. fs. are dependent upon the primary flux and the speed of rotation and are independent of the primary frequency. Due to the fact that the flux and poles A and B are at 90 deg. relation to each other, these two rotational e. m. fs. a and c are at right angles to each other.

Let us now consider the transformer action of the primary fluxes acting on the secondary. The rotor winding along the axis of pole or phase A will generate an e. m. f. d 90 deg. out of phase with the flux of phase A. This is indicated in Fig. 1. Also the winding along axis B will generate a transformer e. m. f. b. In the winding under pole A, therefore, there will be two component e. m. fs. a and b, which are in opposition to each other, a being in phase with the flux in phase A, and b being 90 deg. out of phase with the flux B, which in turn is 90 deg. out of phase with flux A. Thus a and b are 180 deg. part, neglecting minor effects. In the same way, under pole B, e. m. fs. c and d are approximately 180 deg. apart.

Obviously, the rotational e. m. fs. a and c are dependent upon the speed of the secondary and therefore vary from zero, at standstill, to values equal to b and d when the rotational frequency (poles times revolutions) is equal to the line frequency; for with equal fluxes, equal frequencies, and other conditions, e. m. fs. set up by rotation are equal to the e. m. fs. set up by so-called transformer action. Therefore, at synchronous speed of the secondary, the rotational and transformer e. m. fs. in the secondary windings practically balance each other, in a well-designed machine. Obviously, in the external secondary circuits the e. m. fs. will vary from maximum at standstill to zero at synchronism, considered simply from the standpoint of the component e. m. fs. a, b, c and d, as shown in Fig. 1.

It is evident that the rotational e. m. fs. a and c correspond to the counter e. m. fs. in an ordinary motor, while the transformer e. m. fs., b and d, correspond to the impressed e. m. fs. Thus by comparison, the rotational or counter e. m. fs., a and c are zero at standstill and rise in value until they are practically equal to the impressed e. m. f., as in ordinary types of electric motors.

Now as to the frequency of such secondary circuits,—at standstill obviously this must be the same as the primary or supply frequency; and as the secondary winding is rotated in the direction of the primary rotating magnetic field, the secondary frequency will decrease, reaching zero at synchronism with the primary field. Thus the secondary voltage and frequency both are dependent upon the speed of rotation. This, of course, is all an old story, but is brought in here simply as part of the problem of commutation and speed variation.

If the secondary circuits are connected to the secondary windings by means of permanent connections, then obviously, the points of connection will rotate with the secondary core. If, however, the secondary winding is provided with a commutator and the secondary circuits are connected to the secondary winding by means of brushes on such commutator, then the connection of the secondary circuits to the secondary winding becomes a variable or movable one, depending upon the motion of the brushes relative to the commutator. If the brushes are in a fixed position on the commutator, as shown in Fig. 2, then the secondary connections are fixed in space, so to speak, instead of rotating with the secondary winding. In such an

arrangement, the frequency of the external secondary circuits at any speed is the same as with the usual induction motor at standstill. In other words, it is always the same as that of the supply circuit, although the e. m. fs. in the secondary circuits will vary with the speed, as in the ordinary induction motor. Consequently, this arrangement differs from the usual induction motor, in having full line frequency, with varying voltage, in the external secondary circuits, whereas the usual induction motor has varying frequency and varying voltage in such circuits. The interesting feature in this arrangement is that we now can supply e. m. fs., at line frequency, to the secondary circuits for speed control. From an inspection of Fig. 2, it is obvious that for stable conditions, e. m. fs. *a* and *b* must balance if no other conditions are introduced; that is the motor will tend to run up to synchronous speed. However, if external e. m. fs. respectively in phase with *a* and *c* are added, then these e. m. fs., plus *a* and *c* can balance *b* and *d* at some other than synchronous speed, and thus stability is obtained at other than synchronous conditions. It is thus evident that,

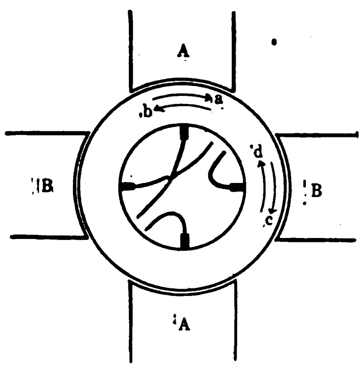

Fig. 2

by means of the commutator, we are able to introduce into the secondary circuits suitable e. m. fs. at line frequency to accomplish this result, and this is one of the methods which has been used in the past for speed control of polyphase motors. The A. E. G. Co., of Berlin, has built such motors, in which the supply circuits for the secondary voltage regulation are obtained from special windings on the primary, with a number of taps to give different voltages. In other arrangements transformers have been used for converting from the line to the desired secondary voltages, with a number of taps for varying such voltages.

The above covers broadly this general method of speed control. Let us look now into the problem of commutation in such machines, as determined by the e. m. fs. short-circuited by the brushes. In the first place, at standstill the volts per conductor or turn are practically the same as in the primary winding, and the e. m. f. spanned by the brush is dependent upon the volts per turn and the number of turns short-circuited. In the second place, as the secondary speeds up, its resultant volts per turn decrease directly as the speed increases, for the rotational e. m. f. per turn is rising and more nearly approaches in value the opposing transformer e. m. f. per turn. The e. m. f. short-circuited by the brush decreases accordingly, reaching practically zero value at synchronous speed in a well-designed machine, and again rising in value above synchronism. This is the resultant e. m. f. due to the primary flux. If this resultant were the only e. m. f. to be considered, the problem would be fairly simple in its explanation. However, there are other magnetic fluxes due to the rotor magnetomotive forces, as in d-c. machines, which also set up e. m. fs. and the inclusion of these complicates the explanation. These latter, however, are usually small compared with the resultant short-circuited e. m. f. due to the primary field, and in most cases are largely masked by the latter, except near synchronism. Ordinarily the conditions which tend to give a low short-circuited e. m. f., due to the primary field, also tend to reduce these lesser e. m. fs., so that in general one need consider only the larger e. m. f. due to the primary field. By reducing this to a value within the limits of resistance commutation, and proportioning the armature so that it would be very good for commutating a corresponding direct current, one usually need consider nothing else, for practical purposes. Obviously, in the motor just described the commutating conditions will be easiest near synchronism and will become increasingly difficult with departure from synchronous speed. In practise, the permissible limit of short-circuited volts for operative commutation may be reached anywhere between synchronism and standstill, depending upon the design.

From the preceding description, it is evident, in the general problem of speed control, that we must take into consideration the frequency of the current handled by the circuits connected to the brushes on the commutator. While this may have little bearing on the general question of commutation, it is one of the important features in the general scheme of speed variation or control of the induction motor. Therefore where there are two (or more) sets of circuits connected to one or both motor windings, it may be advisable at this point to show in a simple way the relation of the frequencies in these circuits. Such circuits may be connected to the windings, either by permanent taps or by variable taps through the medium of brushes on one or more commutators. One set of these circuits may always be considered as a primary or supply system and the others as secondary circuits, whether they are on the primary or the secondary core. A simple rule can be given for the relation of these frequencies in polyphase motors,—namely, *the frequency of any external secondary circuit relative to the primary or supply circuit is determined by the relative angular movement of its points of contact with respect to those of the primary circuit.* If these contacts have a fixed angular relation to each other, then the frequency of the secondary circuits is always the same as that of the primary circuits. If

these are moving with respect to each other, the frequency of the secondary circuits will vary from that of the primary according to the relative movements.

For example, in the usual induction motor, with stationary primary and wound secondary with collector rings, at standstill the stator and rotor taps on the windings have a fixed relation to each other and the frequency of the secondary current is therefore the same as that of the primary. As the secondary core and windings increase in speed, the rotor taps move with respect to the primary and the frequency of the secondary external circuits is thus varied.

In the same way, the motor with a commutator on the secondary and with fixed brushes, will, according to the above rule, give full primary frequency on the secondary external circuits at all speeds, simply because the secondary taps, or points of contact, hold a fixed relation to the primary taps. Any rotation of the secondary brushes will give a varying frequency in the secondary external circuits, depending upon the speed of rotation of the brushes.

There are various modifications of the polyphase commutator-type motor, several of which involve special commutating conditions, and therefore should be described briefly. One of these is known as the Schrage motor. This is a polyphase induction motor with a rotating primary with polyphase taps and collector rings and also with a commutator and polyphase brushes. In its simplest form the commutator and the collector ring taps are connected to a common winding of the closed coil direct-current type. In the more usual form there is a second low voltage winding on the rotor core which is connected to the commutator, the primary winding proper being of higher voltage and not connected to the commutator in any way. By this latter arrangement, the primary supply e. m. f. and the low voltage required on the commutating winding become independent of each other and each can be proportioned for its own best requirements. This may be illustrated, in its arrangement of circuits by Fig. 3. Here only a single primary winding is shown, for simplicity, with both the collector rings and the commutator connected to it. $A\ A\ A$ represent three sets of fixed brushes, while $B\ B\ B$ represent movable ones.

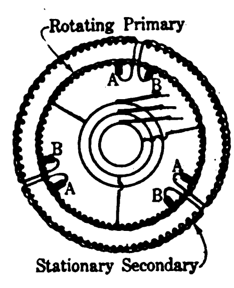

Fig. 3

According to the foregoing method of determining the frequency etc., between brushes A and B, there is a fixed e. m. f., but a frequency depending upon the speed of rotation. Connecting the circuit from $A\ B$ to a phase group on the stator core, the speed will balance at such point that the e. m. f. and frequency of the brushes will equal the stator e. m. f. and frequency. By rocking B to some new position, a different voltage is obtained between brushes A and B and thus a new speed is required for balancing the e. m. fs. and frequencies.

In this arrangement the commutating brushes are fixed in position while the winding, commutator and primary supply taps revolve. Here the primary field or flux travels at a definite speed with respect to the rotor core and windings, the primary current being supplied through the collector-rings and taps to the winding. Just as in a stationary primary, the primary counter e. m. f. and the effective e. m. f. per turn, are constant, as they depend upon the rotation of the primary field or flux with respect to the primary core and windings. Therefore the short-circuited e. m. f. under the brushes on the primary winding is constant and corresponds to that portion of the primary e. m. f. spanned by the brushes. Herein lies one reason for the use of the double primary winding. With a very high applied e. m. f., the number of primary turns would be high and the turns per coil or per commutator bar would be unduly large unless an enormous number of commutator bars is used; but the addition of the low voltage winding allows this element to be proportioned to suit the short-circuited conditions and the number of commutator bars, independently of the primary winding proper.

This arrangement short-circuits the full value of primary e. m. f. per turn at all speeds, but the brushes do not handle current of the primary frequency, but of a frequency depending upon the speed, for the primary taps and the brushes on the commutator are moving with respect to each other, except at standstill. The frequency delivered at the commutator therefore varies from full-line frequency at standstill to zero frequency at synchronous speed. However, the voltage delivered from the winding to the brushes is practically constant at all speeds. The result therefore is just the opposite of that described in connection with the polyphase motor with a commutator on its secondary, for in that case the frequnecy delivered at the commutator was constant and the voltage varied with the speed, whereas in this latter case, the frequency varies with the speed and the voltage is constant with a given brush setting. As the frequency and voltage of the stator winding of this motor both vary with the speed, as in the usual induction motor, it is thus possible in this motor to obtain speed regulation by connecting the circuits from the primary commutator brushes directly to the secondary winding, provided voltage adjustment is obtainable. This, of course, can be accomplished by means of transformers and in various other ways, but in the Schrage motor, as built, this is obtained by the two sets of brushes on the commutator, as shown in Fig. 3, which can be displaced with respect to each other, so that the voltage between them can thus be varied up or down by suitable setting of the brush arms. In this way the armature winding and the commutator are used as the equivalent of a transformer with variable voltage taps, so that both frequency and voltage are thus under control.

As far as commutation is concerned, this scheme is

at a disadvantage compared with the previously described arrangement with the commutator on the secondary winding in which the short-circuited e. m. f. varies with the slip from synchronism. With this latter scheme, therefore, commutation is to a considerable extent independent of speed, simply because the short-circuit conditions are equally difficult at practically all speeds. If such a machine can be made to operate sufficiently well at any one speed, it should then be suitable for operation over a fairly wide range of speed.

It is apparent from the description of this Schrage motor that the rotor becomes simply a changer of frequency, but not inherently a transformer of voltage. A similar arrangement was devised many years ago by the writer purely as a frequency changer, and it is being used at present in connection with speed control of large induction motors. The rotor of this machine, as shown in Fig. 4, consists of a primary winding on the rotor core connected to both a commutator and a set of collector rings. In operation the core is rotated inside a laminated ring, which may or may not carry any windings. At synchronism with the a-c. supply or primary system, the commutator delivers direct current at a voltage proportional to that of the alternating

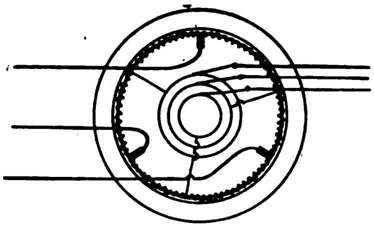

Fig. 4

e. m. f. impressed. With change in speed, either up or down from synchronism, the brushes deliver current at a frequency varying with the slip from synchronous speed, but the e. m. f. delivered is constant with constant supply e. m. f., regardless of the slip. This is therefore a variable-frequency, constant-voltage machine and the conditions of commutation are fixed principally by the primary flux or field, practically regardless of speed. By the use of several sets of brushes, properly spaced on the commutator, polyphase currents are taken from the commutator.

A third form of polyphase commutating motor was proposed in Europe some years ago, in which a stationary primary winding of the closed-coil type is connected to a commutator, and the current is admitted by brushes which are rotatable on this commutator. It is at once evident that this is simply an induction motor primary in which the points of current supply can be rotated around the core. In consequence, the speed of rotation of the primary field, or flux, corresponds to the line frequency, plus or minus the speed of rotation of the brushes. The secondary core and winding, of usual polyphase type, at full speed rotates at practically the speed of the primary field; and accordingly its speed will vary directly with that of the primary supply brushes.

Looking into the conditions of commutation in this type of machine, it is at once noted that, as the brushes short-circuit part of the primary winding which generates the counter e. m. f. of the machine, the short-circuited e. m. f. will be proportional to the counter e. m. f. and therefore will be of practically constant value. Here the conditions and limitations of commutation are fixed almost entirely by the primary e. m. f. short-circuited, and practically no other e. m. f. conditions need be considered. If five volts, for instance, could be taken care of by the brushes, then they would stand an average of five volts on the commutator at any speed within reason. As far as commutation is concerned, this motor is subject to the same limitations as the Schrage motor with a single primary winding.

The above covers briefly the polyphase induction motor with commutator. Polyphase series and shunt types of commutator motors might be considered as next in order, but they are so closely related to various single-phase types, that their treatment, according to the foregoing method of illustration, should properly follow the single-phase. Therefore, they will be taken up later.

Single-Phase Commutator Motors

These may be of various types or forms, such as series, repulsion, doubly-fed and induction types. In these, in general, the commutating conditions are more difficult to analyze and to explain than in the polyphase induction motor, just as the phenomena of single-phase induction motors, in general, are usually more difficult to grasp than those of the polyphase. Also just as the assumption of two component fields of opposite rotation can replace the single-phase field in considering some of the characteristics of single-phase motors, so in commutation of single-phase machines this assumption may be of assistance in some instances, in explaining the actions, although the writer has not used the method in this paper.

Single-phase motors are structurally of two types, namely, of the polar and of the distributed type fields. In practise these are equivalent, but the distributed type, with its overlapping windings and fluxes, introduces such complexity, in any general analysis, that for purposes of illustration, a polar arrangement should be shown. Consequently, in the illustrative diagrams, which are given later in connection with single-phase motors, polar arrangements are given. It might be well, therefore, to show the equivalence of the two arrangements insofar as principles are concerned.

Equivalence of Polar and Distributed Windings. Taking the simplest type of distributed winding,—namely, the *closed-coil, ring type,* other types and arrangements can be developed from it quite easily.

Assuming such a ring-type closed coil, as shown in Fig. 5, then with taps at A and B there will be a maximum m. m. f. at A and B tapering off to zero midway between. Thus there will be magnetic poles with maximum value at A and B and zero at midway points.

The same holds true for a closed coil armature. The maximum m. m. fs. of the armature windings correspond to the points of current connection, as shown in Fig. 6.

Let us consider such an armature in a ring field of this type. Fig. 6 illustrates this. With the brushes

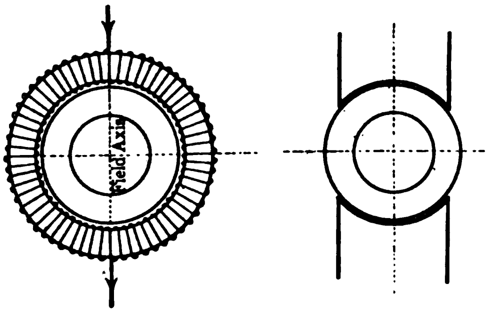

FIG. 5

on the armature at right angles to the field taps, and corresponding to the points of zero field flux, the arrangement is equivalent to the usual d-c. motor with two poles and with the armature brushes on neutral. Here *all* the field winding is magnetizing.

However, let us next shift the armature brushes around to another angle than 90 deg. to the field axis. Assuming a 45 deg. angle, the arrangement is as in Fig. 7. Then all the field winding between A and C, representing double the angle between the armature and field axes, becomes magnetizing or exciting field winding and sets up a magnetic field at right angles to

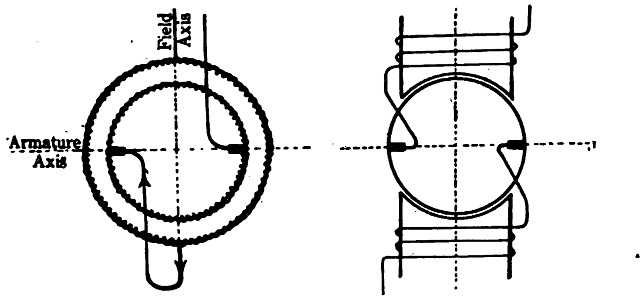

FIG. 6

the armature axis or brushes; while the part of the field winding between B and C represents a m. m. f. acting *parallel to the armature axis*, but in opposite direction to the armature m. m. f. This part of the field winding *thus automatically becomes a compensating winding.*

Taking again a much smaller angle between the field-winding and armature-winding axes, as in Fig. 8, here again the field winding between A and C becomes magnetizing, while that between C and B becomes compensating. Thus by setting the armature brushes at various angles to the field-winding axis, components of the field winding equal to double these angles, become magnetizing, and the remaining parts become compensating. This relation is just as definite, and in fact is the same thing, as using two separate windings for exciting and compensating, connected in series, and with armature brushes at a midway point in the distributed exciting winding. With the two distinct winding arrangements, the relation of exciting to compensating strength can be changed without changing the brush angle, which is not the case with the single

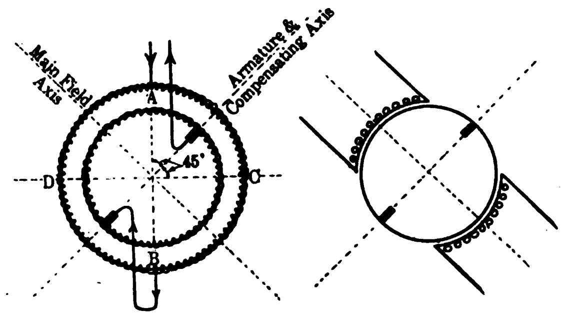

FIG. 7

winding. Or stating the matter in another way, the field strength, and thus the speed, may be changed without shifting the brushes. However, in principle, the arrangements are the same.

The disadvantage in directly representing the polar conditions with distributed windings, in the various single-phase motors illustrated in the following figures, is that the overlapping poles and fluxes are confusing to almost everyone except the designer. In consequence, the writer has shown the fluxes as separate

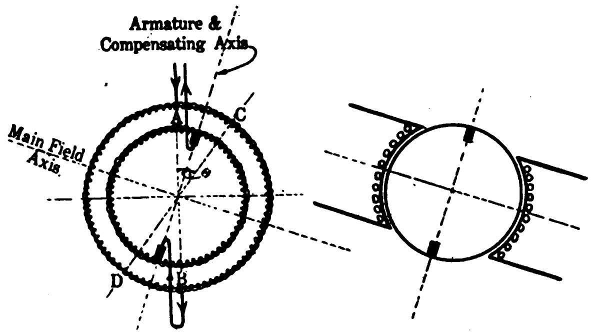

FIG. 8

magnetizing and compensating or transformer components in order to illustrate more easily the principles of operation and of commutation.

Single-Phase Series Motors. Of all the single-phase motors, presumably the straight series type is one of the simplest to explain from the standpoint of commutation, as well as otherwise. This motor is, in effect, just like a d-c. series motor of similar general construction and the performance is much the same. However, it differs from the d-c. series motor in one essential point; namely, there are two e. m. fs. set up in the armature

winding, although not along the same axis, these e. m. fs. being the rotational and the transformer e. m. fs. due to the main field flux. This is illustrated in Fig. 9. The rotational e. m. f. is along the axis of the brushes, while the transformer e. m. f. is along the field axis, and at right angles to the rotational, and therefore has no direct influence on the latter. However, the brushes short-circuit part of the transformer e. m. f., as will be considered further.

In its commutation the series motor embodies the equivalent of the usual d-c. problems, plus the additional one due to the transformer e. m. f. in the armature windings. Thus there are two short-circuited e. m. fs. to take into account, one being due to rotation in the armature field or flux, and the other to transformer action. These are 90 deg. out of phase with each other. This, together with the fact that one of these e. m. fs. is dependent upon armature speed while the other is independent of it, makes any commutating pole problem quite difficult, for this type of motor is used principally where speed variation over a wide range is one of the requisites. However, it is the transformer component which is the great handicap in

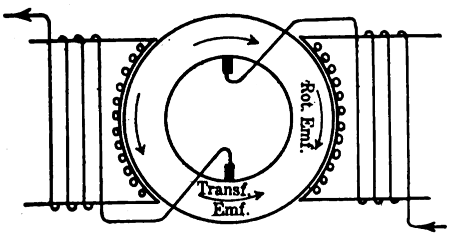

Fig. 9

a-c. commutation in general, for it is not possible to counterbalance completely such an e. m. f. under all conditions, by any corrective e. m. f. depending upon rotation, as is done in d-c. machines; for at zero speed this transformer e. m. f. still exists at full value, whereas no rotational e. m. f. is possible under this condition. Therefore, in this, as in all a-c. commutator motors, the standstill condition represents a limit where compensation, or the commutating pole in any form, is ineffective. Under this condition, however, only the transformer e. m. f. is short-circuited by the brushes, all rotational e. m. fs. being absent.

As this transformer e. m. f. in the short-circuited coils is proportional to the main field flux, it might be assumed that there could be a considerable gain by reducing the field flux during starting and at lower speeds. However, this cannot be carried very far, for the torque of the motor also depends upon the main field flux, and thus any reduction in this flux means correspondingly increased armature current,—so that the reduction in the short-circuit or local current is accompanied by an increase in the work current.

In his early work on single-phase commutator motors, the writer recognized the condition of a limiting e. m. f. which could be short-circuited successfully by the brushes, and his early experimental designs were all along lines of obtaining a sufficiently low transformer e. m. f. Low frequency, of course, was one of the recognized factors in accomplishing this. Mechanical limitations in the number of commutator bars, width of brush, etc., and the electrical limits of volts per bar, at once dictated that the counter e. m. f. of such a machine must be relatively low. There was much criticism at that time regarding the adoption of such low voltage for a-c. series motors,—about half that of d-c. railway practise,—but it may be noted that no one in the succeeding twenty years has been able to increase greatly over the armature voltages which were first used, with motors of corresponding speed and capacity. Here appeared to be a fundamental limitation, partly of a mechanical and partly of an electrical nature.

In the study of the short-circuited transformer e. m. f., it appeared at that time that somewhat higher short-circuited e. m. f.s. under the brush would be allowable, by including a considerable amount of resistance in the short-circuited paths, in order to reduce the short-circuit current. In consequence, the use of resistance, or preventive, leads, between the commutator and windings, was proposed and tried with the result that materially higher short-circuited e. m. fs. proved to be practicable, and thus correspondingly higher main flux densities were permissible. The writer has never carried this construction to its extreme limits, as no very good opportunity offered itself. The use of resistance leads for such purpose was not new or novel, but the writer believes the results he obtained were much more satisfactory and conclusive than in former trials, largely because the leads were applied with due regard to the electrical limitations of the short-circuited e. m. f. and the values of local and work current, etc.

In the early days the writer also gave serious consideration to the problem of commutating poles on series a-c., single-phase, motors and even carried this to the extent of trying it out on a 300-h.p. motor. This was not for the purpose of eliminating the resistance leads, as he did not believe at that time that this was practicable, on account of starting conditions, but it was for reducing the short-circuited e. m. f. under the brushes, while in rotation, by introducing a counter-acting e. m. f. Unfortunately, these tests were carried out entirely with series excited commutating poles. There was a very considerable improvement at high speeds, but at moderately low speeds no improvement was apparent. Of course, it was recognized, even at that time, that the transformer e. m. f. under the brush was out of phase with the armature current and it was doubtless recognized that the phase relation of the commutating pole flux was not just what it should be. However, the general results, as tested, held so little promise, except at quite high speeds, that it was felt that it was not worth while to follow this matter up

further. At that time the proportioning of commutating poles and commutating-pole windings was not very well understood, even on direct machines, so it is not surprising that anyone should be misled on the a-c. machine.

More recent work on commutating poles in such motors has shown that properly proportioned poles and windings with suitable phase shift of the current will materially improve the commutation over a relatively wide range of speed beginning at fairly low speeds. Experience also shows that, by such means, series motors without preventive leads can be made to give results comparable with motors with such leads, but without commutating poles. Very considerable development has been carried on recently along such lines. These good results are due, largely, to better knowledge of the most desirable proportions, etc. This will be treated more fully, later.

No mention has been made of compensating windings on series motors. Such windings were developed very early, but principally for the purpose of improving the power factor by neutralizing the armature m. m. f. Apparently this did effect some slight improvement in the commutation, but it was possibly a mere question of opinion. Both series-connected and shunt-connected compensating windings were tried, the latter operating fairly well but seemingly representing no physical improvement over the series arrangement. Over-compensation with the winding series connected, appeared to represent little gain. In fact, the compensating winding short-circuited on itself seemed to be just about as effective as any other arrangement, in most of the tests.

Repulsion Motor. Another early development was the so-called repulsion motor, now known as a transformer type. We will retain the older term, as it is better known. At first, this was believed to be a distinct type of single-phase motor, although its characteristics were recognized as being very similar to those of the series machine. In an Institute discussion of repulsion motors, in January, 1904, the writer showed that this type of motor was simply a series type, in which the current in the armature was generated by transformer action, instead of being fed in directly at the brushes. In other words, it is a transformer type series motor. Possibly there was no novelty in this form of treatment, but it enabled one to analyze this type of motor from the series standpoint. This method of treatment also allows the commutation problem to be considered in a fairly simple manner.

A brief review of this method may be given here, not simply for the purpose of showing the relation of the repulsion to the series motor, but to bring out some of the commutating conditions not included in the former discussion, and also to show the close resemblance to some of the conditions in the polyphase induction motor, as described and illustrated in connection with Figs. 1 and 2.

Assume first a series motor with its armature fed from the secondary of a transformer, the primary of which is in series with the motor field. Also assume for simplicity a 1 : 1 ratio of transformation. Fig. 10 illustrates this arrangement.

With a given field flux, the armature winding will generate along the brush axis a rotational e. m. f. directly proportional to the speed, and counter to that of the secondary of the transformer, to which its brushes are connected. This, therefore, fixes the value of the secondary e. m. f. of the transformer and, therefore, its primary e. m. f. Accordingly, with a 1 : 1 ratio the transformer primary e. m. f. is practically equal to that of the armature at all times; and the main field, with this primary e. m. f. in series with it, should act just like the field and armature in series in the straight series motor. Assuming a given main field flux, then the armature rotational or counter e. m. f., and consequently the e. m. f. of the transformer, will vary up and down with the armature speed. Therefore

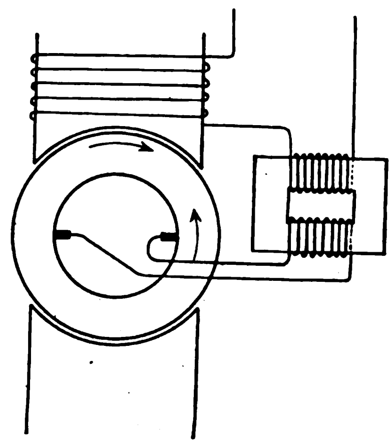

Fig. 10

the magnetic flux of the transformer will thus vary with the armature speed.

The primary current of the transformer necessarily is in phase with the main field current and the secondary current from the transformer will be in phase with the primary, excepting the necessary magnetizing component. The current supplied to the armature will, therefore, be practically in phase with the rotational e. m. f., just as in the straight series motor, excepting the small magnetizing current for the transformer, which is 90 deg. out of phase with the primary current, as is also the flux in the transformer. The secondary e. m. f. of the transformer must be just enough out of 180 deg. phase with the armature rotational e. m. f. to allow the necessary transformer magnetizing current to flow.

Such an arrangement, in general, can replace the straight series motor. It is different from the series motor, in that the armature can be proportioned for its own best voltage and current conditions, regardless of line conditions. It also differs in the fact that the armature furnishes exciting current for the transformer.

It should be noted also that minor effects due to magnetic leakages, etc., are neglected in the above treatment.

In the repulsion type motor, instead of a separate transformer with its own primary and secondary windings, the magnetic circuit of the motor itself is used as a transformer core, and the armature winding is used as the secondary winding of the transformer. Thus the secondary voltage supplied to the motor, and the rotational e. m. f., are both generated in the same winding.

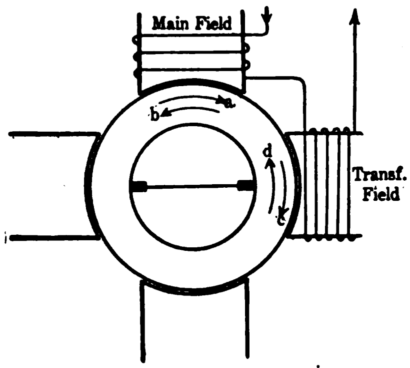

Fig. 11

Fig. 11 illustrates such an arrangement. Here the transformer magnetic circuit is across, or at right angles to, the main magnetic circuit.

In operation, the counter e. m. f. *a* is generated along the brush axis by rotation under the main field. Also, due to the transformer flux, an e. m. f. *b* is generated in the winding along the same axis. If the main current in the transformer winding should generate the transformer flux, then such flux would be in phase with the primary current, and the transformer e. m. f. *b* would be at 90 deg. to the rotational e. m. f. *a*. But this represents an unbalanced condition with the brushes short-circuited on themselves, as in Fig. 11, and heavy currents will tend to flow, correcting the unbalanced voltage conditions. The result of this is a magnetizing current for the transformer magnetic circuit which gives a resultant flux in the transformer pole lagging 90 deg. from that in the main poles. This 90 deg. lag in flux thus throws the transformer e. m. f. *b* practically 180 deg. out of phase with *a*; that is, directly in opposition to it, as described in connection with Fig. 10. Thus there are generated in the armature winding two practically equal and opposite e. m. fs. However, the *fluxes* in the two fields are not equal or equivalent except under certain conditions. The e. m. f. *a* depends upon the main pole flux, and upon the speed, which is variable while e. m. f. *b* depends upon the transformer pole flux, and the frequency of the main system which is constant. When the rotational frequency (revolutions times poles) becomes equal to the line frequency, the two sets of field fluxes become equal, or equivalent, in generating e. m. f., and therefore, the motor is similar to a polyphase motor with its armature rotating at synchronous speed, which, as already described under Polyphase Motors, gives zero frequency and e. m. f. in the rotating armature coils.

Under the condition of equal fluxes the commutation is best, as in the polyphase motor with a commutator type armature, for the coils short-circuited by the brushes have in them a transformer e. m. f. generated by the flux of the main poles, and a practically equal and opposite rotational e. m. f. generated by the transformer poles. Due to these two principal fluxes being 90 deg. out of phase, as already explained, the two e. m. fs. balance each other in the short-circuited coils; which is simply another way of stating the above condition of zero e. m. f. at synchronous speed.

At standstill, the transformer e. m. f. in the short-circuited coils, due to the main flux, exists just as in the series motor, but there is no rotational e. m. f. from the transformer poles to neutralize it. This, therefore, is the same as in the series motor, but between standstill and synchronous speed, the resultant short-circuited e. m. f. falls with increase in speed. The commutation thus improves with speed, much more than with the series motor.

It has been shown in connection with Figs. 10 and 11, that for a fixed main field the transformer field is low at low speed, and increases with the speed until at synchronism, it is equivalent to the main field,—that is, it varies directly with the speed. Let us see the effect on commutation above synchronism. At all speeds the short-circuited e. m. f. due to the transformer action of the main poles, is constant with constant flux, but the rotational e. m. f. in the same short-

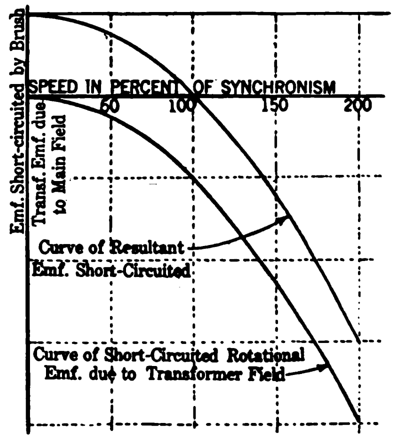

Fig. 12

circuited coils, due to the flux from the transformer poles, increases rapidly with speed, both on account of the increase in speed and the increase in the transformer flux, which also varies with the speed. Consequently, the rotational e. m. f., due to the transformer field, increases as the square of the speed.

These e. m. f. conditions may be illustrated in Fig. 12. Here it may be seen that the resultant e. m. f. under the brush falls slowly, slightly above standstill, but quite rapidly near synchronism. Above synchron-

ism it increases rapidly. At 41 per cent above synchronous speed, it is equal to the standstill value, and at 100 per cent above synchronism, it is three times as great as at standstill. Of course, this is simply an illustrative condition, as the actual values do not follow rigidly the above conditions, the phase relations of the two e. m. fs. not being at exactly 180 deg. But this method of showing the commutating conditions gives a good conception of why the repulsion motor sparks badly at much above synchronous speed.

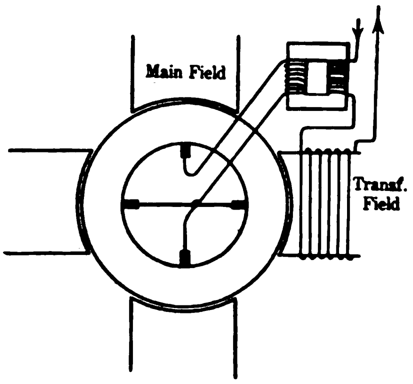

FIG. 13

Armature Excited Repulsion Motor. A modification of the above type is the Winter-Eichberg motor built by the A. E. G. Co. of Germany. This is illustrated in its simplest form in Fig. 13. The only material difference between this form and the repulsion motor shown in Fig. 8 is that the stator exciting windings are omitted and excitation is supplied to the armature instead, by a set of brushes midway between the usual brushes.

To generate the main field flux, it takes a given m. m. f. whether the windings are placed on the main poles or on the armature. However, when placed on the poles the main flux sets up a counter e. m. f. in the field coils at 90 deg. to the current, thus materially affecting the power factor. When placed on the armature, there is a corresponding m. m. f. set up, with the armature at standstill, but, as shown before, at synchronous speed the armature e. m. f. is practically zero; that is,—the exciting m. m. f. can be supplied at practically zero volts, thus greatly improving the power factor. Such improvement lessens, however, with departure from synchronous speed.

Another way of looking at this is that the main flux through the armature winding sets up a 90 deg. displaced e. m. f., just as in a stator exciting winding, but the transformer field sets up, by rotation, an opposing e. m. f., so that the resultant e. m. f. varies from full reactive e. m. f. at standstill to practically zero at synchronous speed.

This motor has practically the same commutation problems as the ordinary repulsion motor except that it has twice as many brush sets. The exciting set, however, does not present much of a problem as far as current capacity is concerned, as the exciting current is relatively small, compared with the normal work current carried by the other set of brushes. The short-circuiting conditions, however, may be the same as for the main brush set. It may be mentioned, before leaving this type, that in practise the exciting current is usually supplied through a small transformer the primary of which is connected in series with the transformer-pole winding.

Doubly-Fed Motor. The above treatment of the repulsion motor leads directly to another later type, which has been used considerably; namely, the doubly-fed motor, as it is usually called. On first inspection this appears to be a combination of the series and the repulsion types, in that the armature is connected in series with the main field winding, and that it also has a transformer field like the repulsion motor. However, the transformer field differs in the fact that it is connected across a section of the main supply transformer, and thus, in reality, is in shunt relation to the armature and main field windings. This allows control of the transformer e. m. f. in the armature winding, and also of the rotational e. m. f. due to the transformer flux. The general arrangement is illustrated in Fig. 14. Here it is seen that the main field and the armature windings are in series, as in the series motor, the transformer winding being across part of the main transformer. In consequence of this shunt connection of the transformer, its magnetizing current is supplied from the transformer, instead of the armature winding, as in the true repulsion motor, and the magnetizing current and flux lag 90 deg. The transformer e. m. f. *b* generated in the armature winding is at 180 deg. to e. m. f. *a*, just as in the repulsion motor, but *b* now can have any value, regardless of *a*, depend-

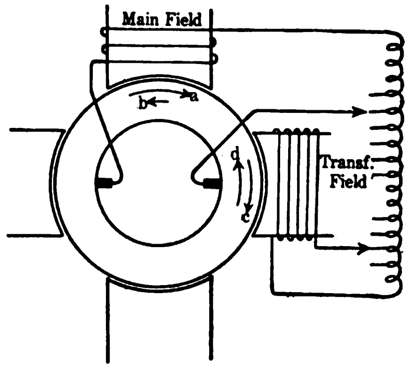

FIG. 14

ing upon the flux in the transformer pole, which is dependent in turn, upon the main transformer e. m. f. supplied to the transformer pole winding. Thus the principal condition of this arrangement is the non-dependence of *b* on *a*, although they are in practical opposition. Their difference appears as an e. m. f. between the brushes. By adjusting the e. m. f. supplied to the transformer winding, to make the e. m. f.

b equal to *a*, the two brushes could be connected together, as in the repulsion motor.

When it comes to commutation, this motor differs materially from the repulsion motor. It is evident that if the transformer pole flux is adjustable in value, then the e. m. f. *d* due to transformer action of the main field can be balanced by the rotational e. m. f. *c* at other than synchronous speed. Consequently, the resultant short-circuited e. m. f. under the brush can have its minimum value at any desired speed, within the limitation of this type of motor. This can be illustrated as in Fig. 15.

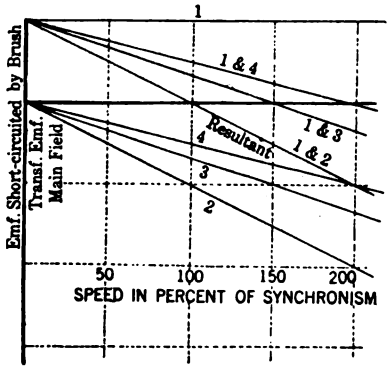

Fig. 15

Assume, as in the repulsion motor conditions in Fig. 12, that the main field is of constant strength. Then the transformer e. m. f. in the coils short-circuited by the brush, due to the main pole flux, is of constant value, as shown in *l* in Fig. 15. However, the e. m. f. in the short-circuit coil due to rotation in the transformer field, is proportional to the speed, instead of the speed squared, for the transformer flux does not vary with the speed, as in the repulsion motor. This is shown as curve *2* in Fig. 15. By weakening the transformer field, the rotational e. m. f. could be changed to 3 or 4. Thus the point of complete neutralization of the two short-circuited e. m. fs. can be shifted to various speeds, and the commutation is thus under better control than in the corresponding repulsion motor. The principal advantage taken of this in is running above synchronous speed, where the usual repulsion motor is bad, as shown in Fig. 12. The method could be used below synchronous speed also, but the flux from the transformer pole would have to be larger than that in the main poles, which, in general, means a larger machine. As a matter of simplicity in control, such motors are sometimes operated as repulsion motors below synchronism, and as doubly-fed at the higher speeds, where weaker transformer fields are used.

In practise, in order to reduce the short-circuiting at start and low speeds, it is not unusual to weaken the main field a small amount, possibly as much as 25 per cent to 30 per cent. This simply helps the low speed conditions, but does not have any material effect at the higher speeds and the main field is restored to normal value by the time any considerable speed is attained.

The Commutating Pole Series Motor. The next step from the doubly-fed motor is to the series motor with commutating poles with phase displacement. In fact the doubly-fed motor with its adjustable transformer pole strength may be defined as one form of commutating pole series motor. The commutating pole series motor, proper, is simply a series a-c. motor, with main and compensating windings in series with the armature and with small commutating poles in addition, as shown in Fig. 16. The commutating poles may generate a small opposing e. m. f. *b* in the armature winding, but on account of the small size of the poles themselves, this effect is almost negligible, compared with the doubly-fed motor, and it is opposed by a corresponding e. m. f. in the compensating winding. However, it is intense enough, in its flux, to set up the necessary opposing e. m. f. in the short-circuited armature coils. By suitably exciting it in the 90 deg. relation, as in the doubly-fed motor, it can do what the latter motor does, and in addition, can be over-excited below synchronous speed, without the disadvantages of the transformer pole in the doubly-fed type, as its total flux is quite small, in comparison. Thus it can give considerable correcting effect at quite low speeds, which is a material advantage. Furthermore, by exciting at some other than the 90 deg. relation, it can also be made to assist in neutralizing the so-called reactive voltage of the armature (corresponding to d-c.). For this latter the commutating pole flux should be

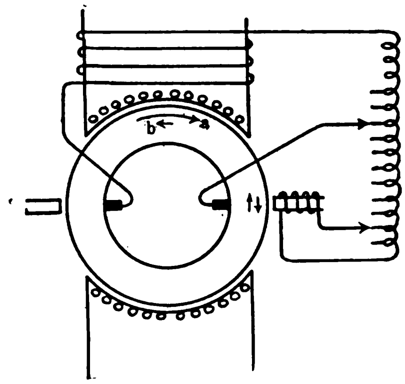

Fig. 16

more nearly in phase with the main flux. Consequently by exciting the small commutating poles by a combination of series and shunt connections, an average best condition is obtained; but this changes with the speed, and must be adjustable for best results. One relatively simple and effective means for obtaining the desired phase-shift, in the commutating poles, is by means of a series winding on these poles, this winding being shunted by a suitable resistance. This arrangement, patented by Latour, has been used to a considerable extent in Europe, especially by the Oerlikon Company.

The foregoing descriptions cover only the general arrangements of single-phase series type motors, with regard to commutation. Many variations have been tried out from time to time, but it is beyond the scope of this paper to go into all such methods. Latour and Alexanderson have been pioneers in the doubly-fed type and they have devised most excellent schemes and methods, both for this and other types, which, in principle, are embodied more or less in the preceding descriptions.

Single Phase Commutator Type Induction Motors. These are of various types resembling, in many ways, the polyphase commutator and the repulsion types already described. However, an analysis of one characteristic type, from the commutation standpoint will be sufficient. The so-called repulsion induction type will be considered, as it bears a very close resemblance in many ways to the repulsion and the doubly-fed motors. An illustrative arrangement of such a

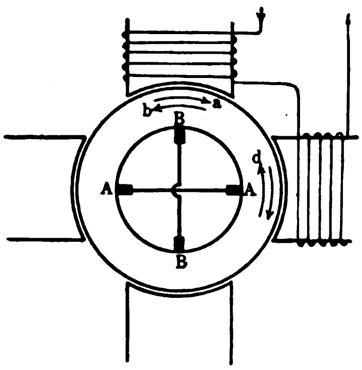

Fig. 17

motor is shown in Fig. 17. It has been shown in connection with Fig. 11 and the repulsion type motor, that at synchronous speed of the armature, with respect to the line frequency, there is zero frequency in the armature winding. The e. m. fs. a and b are balanced and so are e. m. fs. c and d, due to transformer action of the main flux and the rotational e. m. f. from the transformer flux. Consequently, under this condition, another pair of brushes, short-circuited on itself, could be placed at right angles to the repulsion motor brushes, or in fact, could be placed anywhere. Let us assume them at the right-angle position.

In the repulsion motor, at other than synchronous speed, the main field and the transformer fluxes are unequal, or not equivalent, as brought out fully in the former description. Under such conditions e. m. fs. c and d will be unequal and the addition of the second set of brushes, shown in Fig. 14, would result in a considerable current flow. This will be in such direction and value as will equalize e. m. fs. c and d, or in other words, *it equalizes the flux values of the main and transformer poles*, so that the motor maintains practically synchronous speed over its operative range,—that is, it operates very much like an induction motor. Obviously this represents quite good commutating conditions, as in the repulsion motor at synchronism.

Like the doubly-fed motor, balanced voltage conditions can be obtained at the repulsion motor brushes, at other than synchronous speeds, by the introduction of an e. m. f. at the repulsion motor brushes. Assume, for example, that an e. m. f. of proper phase relation with a value of 20 per cent of b is introduced, thus making b equal to 120 per cent of a. To balance this, the speed should rise, or the main field should strengthen, or the transformer flux should weaken, or part or all of these may modify in value. Let us assume, as a rough approximation, that the speed rises 10 per cent, the main field is strengthened 5 per cent and the transformer flux weakened 5 per cent. Then e. m. f. a becomes 115 per cent, due to the speed and the stronger main field, while b with its 20 per cent addition is reduced to 115 per cent by the weakening of the transformer field, thus balancing these two voltages. Then d due to the transformer action of the 5 per cent stronger main pole, becomes 105 per cent and c due to 110 per cent speed and 95 per cent transformer pole flux, becomes 105 per cent also, thus giving balanced voltages between the rotational and the transformer actions. Here we have unequal voltages along the two axes. As far as commutation is concerned, there is practically a balance in the short-circuited e. m. fs. under the A set of brushes. However, it is obvious from the above, that under the B set the two e. m. fs. do not balance and the unbalance increases with departure from synchronous speed.

Polyphase Series and Shunt Motors

a. Series Motor. The polyphase series motor differs from the polyphase induction motor with commutator, in the fact that the counter e. m. f., opposing the primary impressed e. m. f., is not generated in the primary winding, but is generated directly by the armature, as in a d-c. series motor. It resembles the single-phase series motor, in that the total current in the primary winding becomes magnetizing and the e. m. f. generated in the field and armature windings must sum up vectorially to the line impressed e. m. f. Assuming as the simplest case a two-phase series motor, this may be considered roughly as two single-phase motors, structurally at right angles, and with a common armature. This is illustrated in Fig. 18.

In the circuits between brushes A_1 A_1, two e. m. fs. are generated, a due to rotation in field A and b due to transformer action of field B.

As in the polyphase motor, illustrated in Figs. 1 and 2, a can be considered in the nature of an armature counter e. m. f. and b as an impressed e. m. f., in this case adding to the line e. m. f. However, the addition of compensating windings on the field structure affect this condition. Such windings are added primarily for neutralizing or compensating the armature m. m. f. along the axes $A_1 A_1$ and $B_1 B_1$. Diagramatically,

around the B pole or flux there should be compensating windings in phase with the A phase armature windings, but opposing. Practically they would be connected in series with the A phase. The effect of the B flux on the A phase compensating winding is to generate in it a transformer e. m. f., practically equal and opposite to the transformer e. m. f. b in the armature. This was referred to briefly in connection with the commutating pole series motor, Fig. 16. In consequence, as a resultant, there is left only the rotational or counter e. m. f. a, as in the series single-phase motor.

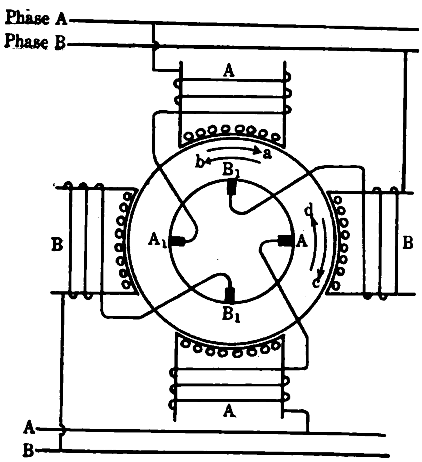

Fig. 18

Phase B with its poles, armature winding, etc., can be treated just as phase A; and thus it is seen that such a motor is quite similar to two superposed single-phase compensated motors with their torques at 90 deg. Thus such a motor will not have the pulsating torque of the single-phase series motor.

In such a motor the commutating conditions are quite similar to those of the single-phase motor at standstill conditions, but are much better as synchronism is approached, just as in the polyphase induction motor with commutator. While the transformer e. m. fs. b and d are opposed by similar e. m. fs. in the respective compensating windings, so that their resultant effects between machine terminals are practically zero, yet the two component e. m. fs. remain in the windings,—so that in the armature, for instance, a opposes b in the coils under the B_1 B_1 brushes and c opposes d under the A_1 A_1 brushes. As synchronism is approached, these opposing e.m.fs. in the coils short-circuited by the brushes more nearly balance each other, just as in the polyphase induction motor with commutator. The conditions of commutation are therefore similar to those in the polyphase commutator motor.

b. Shunt Motor. The polyphase shunt type commutator motor is quite similar to the polyphase series type, except that the field windings are either shunt or separately excited, as shown in Fig. 19. The respective armature and compensating circuits (not shown) are in series and their currents are practically in phase with their rotational e. m. fs. and field fluxes. The field windings being shunt (or separately) excited, must therefore have their exciting e. m. fs. practically 90 deg. out of phase with their respective armature rotational or counter e. m. fs., the A poles being excited from B phase, as shown in Fig. 19. With shunt excitation from constant e. m. f. sources, the field fluxes thus are practically constant, so that such motors tend to maintain constant speed, unlike the series type. The conditions of commutation are so similar to those of the series type that further discussion is unnecessary.

In the above treatment of the polyphase series and shunt motors, the e. m. fs. generated by rotation in the main and in the transformer fields, and also by transformer action due to both fields, have been considered, but there is no reference to the e. m. f. due to the armature field corresponding to that in d-c. commutation. However, as was stated in connection with polyphase induction motors, this e. m. f. is usually quite small, compared with the maximum values of other e. m. fs. short-circuited by the brushes. It is true that where the rotating and transformer short-circuited e. m. fs. practically balance each other, as is the case near synchronism, the e. m. f. due to the armature field may predominate. However, this is in the best part of the commutating range.

In general, the low-voltage, one-turn, parallel-type armature winding and the special proportions used in such machines to obtain desirable conditions otherwise, all tend toward extremely good commutating characteristics on the basis of direct-current commutation,—much better than the average commercial d-c. machines

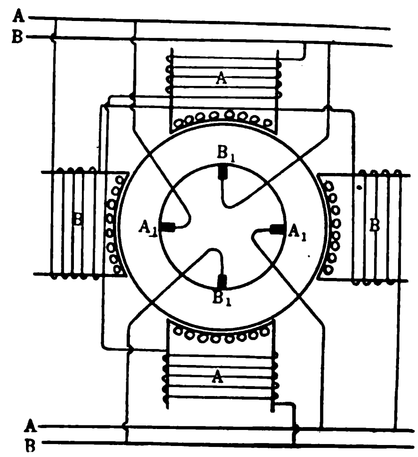

Fig. 19

of the same capacity. Moreover, the e. m. f. under the brushes, generated by the armature field, is usually out of phase with the other short-circuited e. m. fs., or their resultant, so that its inclusion would mean but little change in the problem. Therefore, it has been neglected throughout this entire method of treatment.

It should be noted in connection with the above series and shunt motors, as well as in all of the preceding descriptions, that in splitting up fluxes, m. m. fs., etc., into certain components, it is only for purposes of

illustration and easy explanation. The actual conditions in the machines themselves may be quite different,—for example, where there are two or more currents in a given armature winding, their effects may appear as one resultant m. m. f. of a certain phase relation. The same may hold true for magnetizing, compensating and other windings, and in place of two or more components, a single winding may be used in practise. Also instead of the main and the transformer fluxes acting independently, at any instant there is simply one resultant or combined flux, etc.

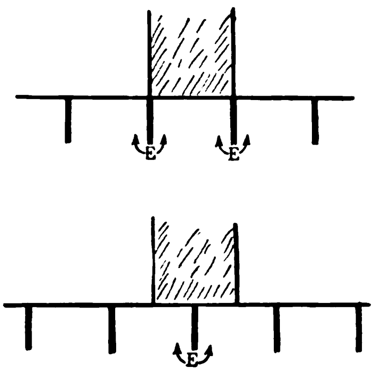

FIG. 20

In the foregoing treatment of the a-c. commutator motors, it should be evident, especially in the case of the polyphase motors, that both speed control and the commutation are dependent upon the relation between the transformer and the rotational e. m. fs., the speed control taking into account the e. m. fs. in the full winding, whereas the commutation involves only that part of the e. m. f. short-circuited by the brushes. This general idea of the relationships of the two characteristics may be expressed in another form,—namely, speed flexibility in induction motors involves change in frequency, which in turn involves the commutation problem in most of the methods and devices used.

In the foregoing treatment of the a-c. commutator motor, the e. m. f. short-circuited by the brush has not been considered in the quantitative sense,—that is, no operative values or limits have been given and the subject would certainly not be complete without some data of that nature. The actual limitations of commutation in a-c. as well as d-c. commutating machines, is fixed principally by the maintenance and life of the brushes and commutator. These depend largely upon the losses due to commutation and the means for preventing harmful effects due to such losses.

COMMUTATION LOSSES AND COMMUTATOR WEAR

It is desirable at this point to consider some of the losses due to the short-circuited e. m. fs. under the brushes in a-c. commutating machines. In the preceding treatment of the rotational and transformer e. m. fs. short-circuited by the brush, apparently it was a question of total volts short-circuited, regardless of the volts per commutator bar. From this view-point, as treated, the number of bars per brush did not come into the problem. For instance, if a given e. m. f. were short-circuited by the brush, this e. m. f. might be generated in one coil of three turns connected to one commutator bar, or in three coils of one turn, each connected to one bar. But a little study of the problem from the standpoint of losses in the brush contact surfaces, as given below, shows this is not so, and that the number of bars short-circuited by a given width of brush may be of considerable importance.

At first glance, one would say that the loss due to the short-circuiting of a given e. m. f. by the brush is simply a question of the value of the e. m. f. and of the brush contact resistance, and that the number of bars spanned is of no consequence as long as the total short-circuit e. m. f. is the same. However, the following results show wherein the number of bars may have a very considerable effect. For example, let us take the case where an e. m. f. E is spanned by the brush. If the brush is the width of one commutator bar, then the average loss is materially larger than if the brush spanned two bars of half width with 0.5 E volts per bar. These two cases can be illustrated by Figs. 20 and 21. In Fig. 20, two positions of the brush with respect to the commutator bars are shown, in one of which the brush short-circuits no e. m. f., while in the other there is the maximum short-circuiting of e. m. f. E. The loss at the brush contact varies from a minimum of

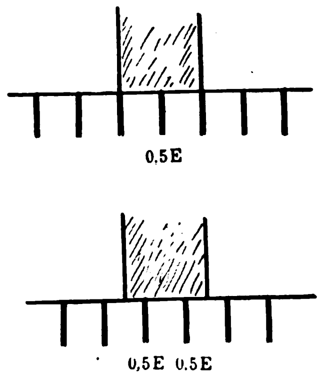

FIG. 21

zero, to a maximum with the brush midway over two bars.

In Fig. 21, two positions of the brush are shown, in one of which the brush spans just two bars, but short-circuits only the e. m. f., 0.5 E, while in the other it is in contact with three bars, and spans a total e. m. f., E. This latter position is that of maximum loss, while the first position shows a minimum, but not a zero, loss. As stated before, it would appear, without analysis, that the average total loss would be practically the same as in Fig. 21. But calculation shows that the average total of the first case is 60 per cent greater than

in the second.[3] The general result is indicated in Fig. 22. It appears from this loss curve that there is but little gain, with more than two bars spanned. Also, it usually is thought that the losses would be decreased, with the brush spanning less than one bar. This, of course, is true with a *given volts per bar*, but is not the case with a *given average voltage short-circuited by the brush*, which is the condition where the short-circuit e. m. f. is determined by the primary fields, instead of the armature fluxes.

This question of losses depending upon the number of bars spanned, may also have a bearing on certain results noted in d-c. machines.

The losses due to commutation are dependent upon the voltages short-circuited and the current values and distributions at the brush contact and in the leads

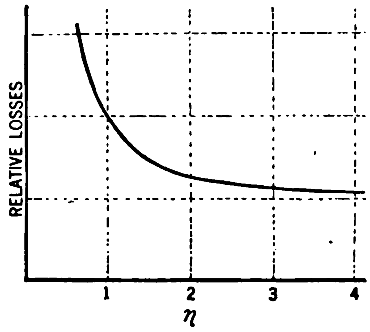

FIG. 22

and coils short-circuited. In "resistance lead" motors or in small motors with relatively high resistance in the coils themselves, a considerable portion of the total resistance in the short-circuited path may be in such parts, thus relieving the brush contact except where the short-circuited e. m. f. is purposely increased with such resistance in circuit.

In all practical a-c. commutator motors the sparking and burning action at the brushes appears to be greatest at starting, and at the lower speeds during acceleration. This is particularly noticeable under those conditions, such as railway work, where the torque at start and at low speed is highest, decreasing with increase in speed consequent upon decrease in main field flux. But even with constant torque the sparking appears worse at lower speeds. With those types of a-c. motors with neutralizing e. m. fs. dependent upon speed, the sparking and deleterious effects on the commutator and brushes decrease with speed up to fairly high speeds. Herein lies one reason why such machines can be made operative without resistance leads even for quite frequent acceleration, as experience has shown. It is because the more severe sparking conditions last for shorter periods than in the non-commutating-pole resistance-lead types; otherwise, the brush contact surface would tend to burn badly and the commutators would blacken due to such burning action. Herein, also, is one reason why the commutating-pole type railway motor, shown in Fig. 16, gives such good brush and commutating conditions. As stated in the description of this motor, the correcting effect of the commutating pole can be carried down to quite low speeds without undesirable effects otherwise.

The real measure of the permissible short-circuited e. m. fs. must be in the operating characteristics, as they affect the commutator and the brushes. Sparking in itself is not harmful in either a-c. or d-c. machines, unless the commutator and brushes show undue deterioration, or require more than usual attention. The so-called "wear" of the commutator copper and the brushes, usually is not true mechanical wear, but is the result of burning at the contact surfaces. All commutating machines are subject to such "wear" in varying degree. Where the burning or wear is at an extremely low rate, the scouring action of the brushes usually will wear down the commutator mica as fast as the copper surface burns away, so that the brush keeps in intimate contact with the copper. In those cases where the rate of burning exceeds the mechanical wear, the mica will ultimately project above the copper and thus "high mica" will result. As soon as this begins, *even in the slightest degree*, the burning action is accentuated, for the brush makes less intimate contact with the copper surface, thus further increasing the burning action. This explains why, in the great majority of cases where commutator burning or undue wear occurs, undercutting the mica makes a very positive improvement,—in many cases apparently entirely eliminating the commutator wear, due to the better contact between the brushes and commutator. This is especially true in railway motors, both d-c. and a-c. and modern practise has tended almost exclusively toward undercutting the mica in such apparatus. Under-

3. The relation of average total loss to the average bars spanned by the loss can be expressed mathematically as follows:

Let e = the e. m. f. per bar.
n = number of commutator bars spanned.
Then $n\,e = E$ = total e. m. f. spanned by brush.
Let r = resistance of brush contact for unit area.
W = width of brush face.

$$\text{Total loss} = \frac{E^2 W}{12\,r}\left(\frac{n^2+1}{n^2}\right)$$

For comparative loss, with $n = 1$, then $\frac{n^2+1}{n^2} = 2$

$$n = 2,\ \frac{n^2+1}{n^2} = 1.25$$

$$n = 3,\ \frac{n^2+1}{n^2} = 1.11$$

$$n = 4,\ \frac{n^2+1}{n^2} = 1.06$$

$$n = \infty,\ \frac{n^2+1}{n^2} = 1.00$$

cutting is particularly beneficial in the former d-c. noncommutating pole types where the short-circuited voltages under the brushes sometimes reached quite high values. In the same way, in a-c. commutating motors, where there are often quite high voltages under the brushes, and a relatively high percentage of mica due to the large number of commutator bars, undercutting of the mica is a practical necessity in all, except, possibly, quite small machines. Even in well designed d-c. machines, other than for railway service, where the mica represents materially above 20 per cent of the commutator wearing surface, experience has shown that undercutting may be needed, even with quite well-proportioned commutating poles. It is obvious, therefore, that the e. m. fs. which can be short-circuited without harmful effects, will vary greatly, depending upon the percentage of mica.

Experience has shown that the burning of the commutator and brushes is largely dependent upon the watts expended at the contact surfaces, as should be expected. Many years ago the writer obtained valuable results from a long series of tests on the collector rings of a uni-polar generator,[4] to determine the rate of wear due to current and contact conditions. It was found that increased contact drop, as well as increased current density, would result in increased wear of the rings and brushes, and that the rate of wear was some function of the actual loss. With a given current density, the contact drop would vary, depending upon the formation of a coating or film under the brushes or on the rings, and if such coating was of appreciable resistance, the contact drop would increase, with corresponding increase in the rate of wear.

In consequence of this condition of wear, due to the losses in the contact, the actual current densities in the brush contacts, as well as the e. m. fs. short-circuited, should be taken into account. But as the local or short-circuited current is a large element in the current density in most a-c. commutation, and as this local current in turn depends upon the e. m. f. short-circuited it so happens that the short-circuited e. m. f. in itself very largely fixes the limiting conditions. Furthermore, as it is largely a question of permissible losses, the peak value of the short-circuited e. m. f. should not be used, especially in comparing a-c. and d-c. limits, but rather some mean value which represents more nearly the average loss conditions.

Commutation Limits. It should be evident from what has already been given that it is quite difficult to fix, even approximately, permissible e. m. fs. which may be short-circuited by the brush, either in a-c. or in d-c. machines. The grade of brush used, the condition of the commutator, the duration of the commutating period, along with many other conditions, all have a bearing on the problem. The short-circuited e. m. f. can be above the harmful point if followed by a sufficient period of scouring action. Starting and acceleration, representing the severest conditions, may be frequent in one case and very infrequent in another. The whole problem is more or less a question of averages. Unless all the conditions are taken into account, there are many apparent discrepancies.

Approximate limits for three operating loads are given in the following table:

(a) Load permitting continuous operation without undue deterioration of the commutator and brushes.
(b) One-hour loads followed by period of lighter operation.
(c) Momentary or very short period load which would be quite destructive if continued for any considerable length of time.

Type of apparatus	Effective e. m. f. Short-circuited		
	Load (a)	Load (b)	Load (c)
D-C. non-commutating pole traction motor (average of 9 sizes)	5 to 7	9 to 11	14 to 17
D-C. engine type Generators (non-commutating pole)	5 to 6	7 to 10	..
Special d-c. 3rd-brush motor—200 h.p.	5 to 6		
A-C. traction motors—doubly-fed and commutating pole types	5 to 6		12 to 14
A-C. traction motors—resistance lead, non-commutating pole types	7.5 to 9	9 to 11.5	13 to 15
A-C. industrial motors	5 to 6.5		
Frequency changers	5 to 6.5	8 to 10	

The above results were obtained from a comparatively large number of machines of each class, except in the case of the third-brush machine cited. This special instance is given, for here a very definite e. m. f. was short-circuited under an active field and good limiting figures were obtainable.

In the case of the d-c. traction motors, the limits given are on the basis of full-line e. m. f. impressed on the motor. Under this condition with load (*a*) the commutator would polish quite well, while on load (*b*) practically all these motors showed some signs of "smutting" at their commutators and the brushes not infrequently showed evidences of burning. Load (*c*) for these motors corresponded to 200 per cent of the one-hour current rating. However, the assumed condition of full-line voltage on the motor is not a normal railway motor operating condition, for, in general, such motors handle these excessive currents only during starting and acceleration,—that is, at reduced speeds with correspondingly reduced e. m. fs. under the brushes.

It might be asked, here, how it has been possible for the d-c noncommutating pole traction motors to operate satisfactorily with as high as 10 volts under the brushes, at more or less frequent intervals, and still continue in good operating condition. In reply, it may be stated that in traction work, there are, in general, considerable periods of coasting, or light service, in which the scouring action of the brushes on the commutator is sufficient to counter-balance the harmful effects of the

4. *Development of a Successful Direct Current, 2000-Kw. Uni-Polar Generator*—Trans., A. I. E. E., June, 1912.

heavier periods. Moreover, experience has shown that the effect of burning under the brushes at heavy loads on these traction motors has been such as to tend to narrow the effective contact face of the brush, thus automatically lessening the average short-circuited e m. f. and the tendency to burn. Also in railway motors which reverse their direction each trip, not uncommonly the brushes tilt slightly in their boxes, depending upon the direction of rotation, so that the brush contacts show two distinct surfaces, each of half the brush width, thus narrowing their effective contacts, and protecting themselves.

In d-c. generators the extreme conditions of short circuit were found, in many cases, where the brushes at no-load were given the greatest possible forward lead in order to take care of the widest range of load without further brush shift. Not infrequently the brushes were shifted into magnetic fields corresponding to five to seven volts across the brushes, or even higher, depending upon the amount of sparking which was considered permissible. Judging from a large number of cases, five to 6 volts short-circuited did not represent an unduly difficult condition.

In the a-c. traction motors of the doubly-fed and commutating-pole types, it has been quite difficult to obtain any very definite data, for here the short-circuit conditions change with the speed and with the adjustment of the compensating windings, and therefore, only average results could be obtained. However, in the a-c. traction motors of the non-commutating-pole type, but *with resistance leads*, quite definite data was obtainable. It will be noted from the table that here the limiting conditions for continuous operation are quite considerably higher than in other types of apparatus, thus indicating quite clearly that the resistance leads, as used, were quite effective in limiting the local currents. On the hour rating, as indicated in column (*b*), these motors do not show materially better than the non-commutating-pole d.c. motors, except that possibly in some cases the "smutting" was a little less pronounced.

The data in the above table, for a-c. industrial motors, were compiled from quite a series of small motors, mostly of variable speed. Here the general results are also somewhat conflicting, but in practically all cases examined, the permissible range of continuous operation was within the figures given. A number of instances were noted where the short-circuit conditions were up to eight or nine volts with apparently fair commutating conditions, but which eventually showed such evidence of deterioration that they were not considered satisfactory. Changing the design of such motors to reduce the short-circuit e. m. f. below the 6.5-volt limit usually made them quite satisfactory.

A number of frequency changers have been built for operation in the secondary circuits of large induction motors for speed control, and fairly definite limits have been obtained from these, as indicated in the above table. Some of these machines have shown quite good commutation at much higher voltages, but after a considerable period of operation, even without visible change in the commutation itself, the brushes would show signs of burning away a part of the contact surface. In such cases, therefore, the real operating limits appear to be in the action under the brushes, rather than in the *visible* commutation. In fact, this was true in many of the cases which were investigated in both d-c. and a-c. machines. The writer has seen many machines of both types, which showed sparking at the brushes, but which showed no evidence of serious burning under the brushes. Conversely, he has seen many cases where the commutation was apparently quite good, but in which there were evidences of more or less rapid deterioration. Thus it may be said that visible commutation is not always a true measure of the permissible short-circuiting action.

An interesting feature of the above table is the fairly close agreement between limiting e. m. fs. for the various types of apparatus. While the writer has felt all along that both a-c. and d-c. commutation were dependent upon approximately the same limits, yet until this paper was undertaken, he had never gone into the comparison as fully as covered in the above table. In former instances, individual cases had been compared, but no attempt had been made to analyze any considerable lines of machines in order to compare the general results. An interesting fact that developed in this study was that a number of machines, which apparently exceeded the above limits, were found, upon further investigation, to have proved somewhat questionable in their operation, after a fairly long period of service.

Isolated cases were found, also, which did not fit in closely with the table, but, as already indicated, no hard and fast rules can be drawn, on account of the large number of variables in the problem.

This paper does not attempt to cover all the characteristics of a-c. commutator motors, but may be considered simply as a review of certain general conditions which affect commutation and speed control. Furthermore, it does not attempt to cover the design of such apparatus. Any wide departure from its present scope would lead into the realm of mathematics, with corresponding reduction in the readability of the article, as far as concerns the great majority of engineers.

Automatic Railway Substations

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This paper reviews the broad range of conditions to which railway automatic substations have been applied and also discusses the economies and operating advantages effected by their use. A description is given of the modern equipment with details of its operation. Special reference is made to improvements in design of control apparatus, to the positive sequence of starting the machines and the protection afforded the apparatus against overloads or other irregularaties either outside or internal to the stations.

PRESENT day railway conditions are such that any improvement leading to the reduction of invested capital or decreased operating charges is of vital importance. Automatic substations as shown by several years' operation have resulted in decided economies and improved operating conditions, and as the subject has not been presented before the A. I. E. E. since an account[1] of the original installation was prepared a review of the modern automatic equipment seems desirable.

The first automatically controlled railway substation was placed in service during December 1914, on the Elgin & Belvedere Electric Railway. The station equipment prior to being made automatic consisted of a single 300-kw., 600-volt, 25-cycle, three-phase synchronous converter with three single-phase 110-kv-a., 26,000-370-volt self-cooled transformer and standard manually-operated switchboard apparatus. The individual devices comprising the first equipments were with but few exceptions, those which had previously been developed by electrical manufacturers for use in other applications. This condition was a decided advantage to the operating companies since developmental charges were eliminated, rendering the equipments comparatively low in cost, which in addition to the successful operation of the early installations made possible the rapid growth of automatic application to electric railways.

Shortly after the initial installation on the Elgin & Belvedere Electric Railway, the two remaining substations on that road were made automatic, followed by the Potomac Electric Power Co. which made automatic a 500-kw. substation. About that time (1916) the Des Moines City Railway and Interurban Railway Co., two adjacent roads, outlined and have practically completed a program involving automatic substations, which has resulted in the most notable example of their use up to the present time. These roads now have in operation a total of three 300-kw. and nine 500-kw., 600-volt automatic synchronous converter equipments. The confidence inspired in the minds of operating engineers and the rapid adoption of this comparatively new phase of electric railway operation was in no small measure accelerated by the successful performance of this rather broad application.

The range of requirement to which the new scheme could be successfully applied was demonstrated when in 1917 two 300-kw., 600-volt, 25-cycle synchronous converters operated in series on 1200 volts by the Milwaukee Railway & Light Co. were automatically equipped. Two automatic substations each containing one 600-kw. 1500-volt d-c. induction motor-generator set were also installed in 1919 by the Salt Lake, Garfield & Western Railway. The Rhode Island Co. have for some time been operating a station containing two 300-kw., 600-volt converters in parallel, while in other localities portable automatic substations have been functioning successfully. Railway converters now automatically equipped range in size from 200 to 1500 kw. with motor-generator sets from 300 to 2000 kw. The total capacity operating in this manner and including those in process of installation is estimated to be 45,500 kw. while the number of automatic equipments involved is approximately 79, 59 of which having been applied to 300- and 500-kw. sizes, and the remainder cover the range of various types and sizes of installations briefly referred to.

While it is the intention to confine the scope of this paper to railway activities, it is interesting to note that a hydroelectric station on the Iowa Railway & Light Company's system containing three 500-kv-a. synchronous generators has been operated automatically since 1917 while the Interstate Light & Power Co. in the same year placed in operation a 3000-kv-a. automatic synchronous condenser. The Union Electric Light & Power Co. is applying the scheme to a 2000-kw., 250-volt lighting synchronous converter. Railway operation, up to the present time, has presented apparently the most attractive field for the use of automatic features, but a well grounded start in other lines has been made and it is only reasonable to expect considerable activity in the lighting and hydroelectric branch of the industry.

Without question a direct reduction in operating expense has been the prime motive for the purchase by railway companies of automatic substations. The saving is effected in several ways, although it is a variable and depends on conditions under which a particular station is operated as well as the number and capacity of machines in the station.

Labor Saving. Considering the several items of saving more or less in their order of importance, the matter of eliminating operator's wages stands out most prominently. In those localities where three eight-hour

1. Allen and Taylor Vol. XXXIV, Part 2, page 1801.

To be presented at the Pittsburgh meeting of the A. I. E. E., March 12, 1920.

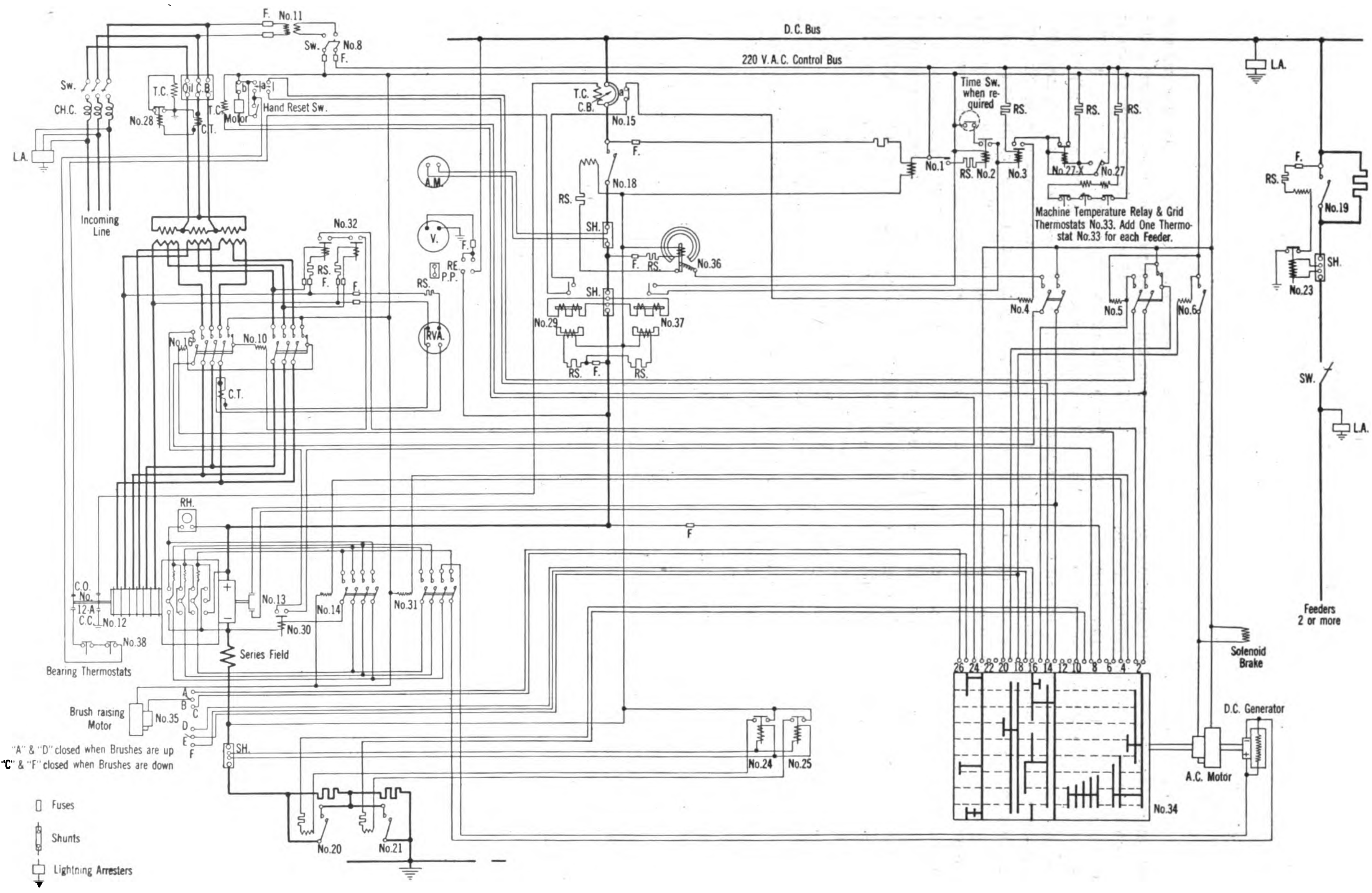

Fig. 1—Typical Wiring Diagram for Automatic Railway Substation

(1) Contact making voltmeter. (2) Time delay starting relay. (3) Time delay shutting down relay. (4) Contactor for making control circuit connections. (5) Contactor for making control circuit connections. (6) Contactor for making control circuit connections. (7) Three-phase oil circuit breaker. (8) 220-volt a-c. control switch. (10) a-c. starting contactor. (11) Control transformer, 220 volts. (12) Speed limit switch (over speed). (13) Speed control switch (under speed). (14) Converter field contactor shunt excitation. (16) A-c. running contactor. (18) Main line a-c. contactor. (19) Feeder load limiting contactors. (20) Converter load limiting contactors. (21) Converter load limiting contactors. (23) Feeder load limiting relays. (24) Converter load limiting relay. (25) Converter load limiting relay. (27) A-c. low-voltage relay. (27x) Auxiliary relay for No. 27. (28) A-c. overload relay. (29) D-c. reverse current relay. (30) Converter field relay. (31) Converter field contactor separate excitation. (32) Single-phase protective relays. (33) Thermostat relays. (34) Motor operated drum controller. (36) Polarized relay. (37) Direct-current underload relay.

shifts are in force in single-unit substations the labor saving alone from automatic operation will often wipe out the original cost of the equipment in two to three years. Where only one or two station attendants are employed, as generally the case on the average interurban system, the net return is not so great, but usually is sufficient to represent a desirable return on the investment in extra equipment incident to automatic operation. When two or three machines are installed in a single station an equal number of complete automatic units are necessary, requiring two or three times the initial investment of a single-unit station. This fact makes it more difficult to justify automatic operation of such a station if only the saving of station attendant's wages is considered. A further study, however, of other savings and advantages inherent to automatic operation as applied to a specific case may show economy of sufficient magnitude to warrant two-unit automatic substations.

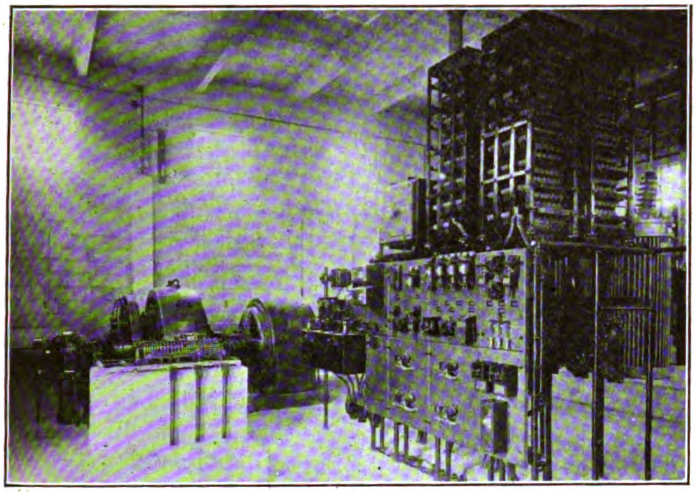

Fig. 2—Interior View of Automatic Substation Containing 600-Kw. 1500-Volt D-C. Induction Motor Generator Set—Salt Lake, Garfield and Western Ry.

The procuring of competent labor constitutes one of the trying difficulties which operating companies have had to contend with during recent years. A natural result of such a condition as applied to manually operated substations is a poor handling of apparatus with a corresponding increase in maintenance costs and less efficient operation. The substitution of automatic stations for the manually operated types eliminates this difficulty in the proportion to the extent of substitution and also reduces the ill effects resulting from labor difficulties. While these features are assets, they are somewhat intangible and not easily capitalized.

A complete elimination of all labor charges against these stations is not feasible since a regular system of inspection must be maintained. Some companies include this work as a portion of a patrolman's or other workman's duties, while other companies which operate several of these stations employ a man who devotes his entire time to this phase of the work. Those stations having high-tension aluminum-cell lightning arresters require daily visits by an inspector to charge the arresters, at which time a casual inspection of the automatic equipment may be performed so as to preclude any minor irregularities becoming serious. Where a reliable high-tension arrester is used which does not require charging such as the oxide film type, two or three hasty inspections per week have been found ample. At intervals of approximately two weeks a thorough inspection should be made and a detailed report prepared to indicate the condition of every device. The amount charged against each station for this service, including maintenance as reported by several companies, varies considerably but will average approximately $300.00 per year.

Light Load Savings. Saving in light load losses, due to automatically shutting down a station when little or no power demand exists, is most noticeable on interurban roads maintaining an infrequent headway. Often a station in manual operation will run idle from a quarter to half the total operating time particularly so if the schedule results in train passing points in the immediate vicinity of the substations. In the event passing points are between stations the machine shutdown period will be somewhat reduced. The total energy saving from this source as applied to single-unit interurban stations depends upon the track layout, characteristics of the schedule and energy required to idle the machine which for a 500-kw. converter equipment is approximately 16 kw.

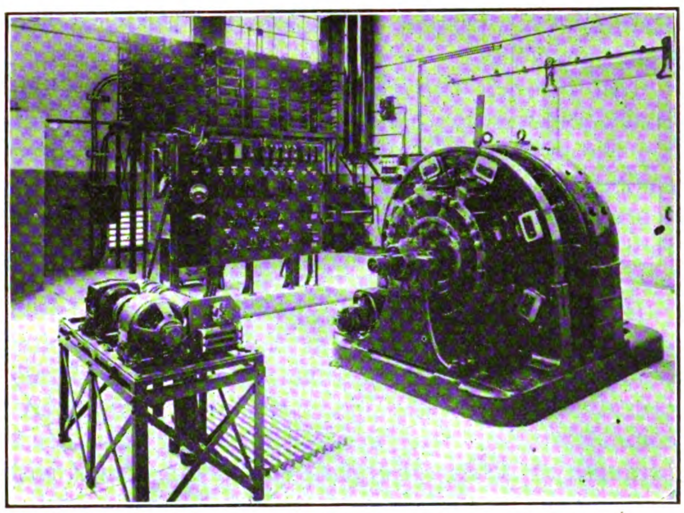

Fig. 3—Interior View of 1000-Kw. 600-volt Synchronous Converter Automatic Substation—Pacific Electric Railway

Energy saving in interurban stations having two machines automatically operated may work out to be very attractive especially if the second machine is used to help out on rush service or move occasional heavy express or freight trains. With automatic operation the second machine would cut in only when a demand for additional power existed and would drop

out when not required. Prompt action in this respect is a decided factor in economy which while not entirely overlooked in the average manually operated substation, is a possible saving considerably neglected.

Two Unit Stations. Combining the savings accruing from the elimination of labor and light-load losses in two-unit parallel-operated automatic stations, together with other advantages, the arrangement is justified as evidenced by the operation of the two-unit station on the Rhode Island Company's system as well as a station now being installed by the Dayton & Troy Electric Railway Co. containing two 300-kw., 600-volt converters and a station on the Cleveland, Railway Co.'s system containing two 1500-kw., 600-volt converters.

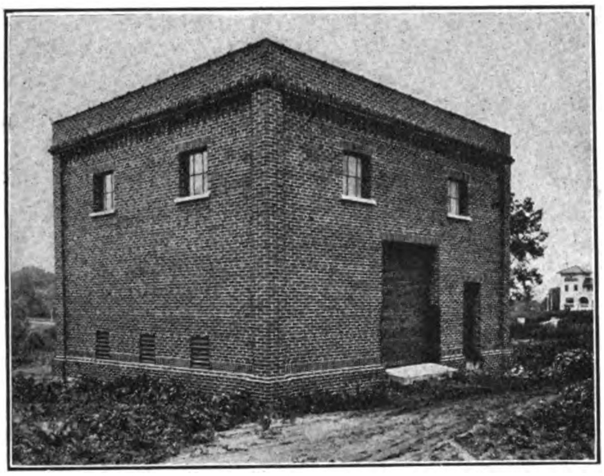

Fig. 4—Exterior View of Polk Boulevard Automatic Substation Containing 500-Kw. 600-volt Synchronous Converter—Des Moines City Railway

Coal Saving. The elimination of coal or perhaps considerable energy used by electric radiators for heating the station or operator's booth is another direct saving attributed to automatic equipments. In the more northern localities this item is sufficient to warrant consideration especially in view of the scarcity and price of coal prevailing in recent years.

Building Design. Building design best to accommodate automatic substations as shown in Fig. 4 is often materially different than that common to manually operated stations. Simplicity, with resulting lowered initial cost, seems to predominate. The structure is arranged to house all apparatus indoors, which with locating the windows out of reach affords a protection from vandalism. Ample ventilation is provided by louvers located in the side walls near the floor level and ventilators in the roof.

Load Factor Improvement. It is a well-known fact that the load factor on the average interurban substation is exceptionally low. Otherwise expressed, this means an unusually large investment in electrical apparatus compared to the average all day power delivered from the station. This condition arises because sufficient capacity must be installed to accommodate not only the regular service, but also to take care of excess demands usually of short duration such as results from accidental bunching of train, snow plows or occasional heavy freight trains. These irregularities because of their rather brief demands on any one station do not, for heating limitations necessitate greatly increased substation capacity, but they do severely tax the station apparatus from the point of commutation and short period capacity. Since in the past there has been no alternative but to provide large capacity machines to protect against these contingencies, the condition of low load factor resulted with high investment charges for the average energy delivered.

The automatic substation functions in a manner partially to remedy the situation so that the average load approaches the maximum load demand on the station, which condition permits increased traffic being served by a given substation or conversely permits a smaller substation capacity to serve a given traffic. This condition is brought about by inserting a high-capacity resistance in the direct-current side of the machine at times of severe overload. The direct purpose of the resistance is to limit the current delivered to a reasonable value, which prevents the abuse of apparatus arising from any load demand. The effect of this device is to cut off the high current peaks so frequent to substations serving rush service, locomotives, heavy freight trains or other requirements where the momentary demands tax the commutation capacity of the machines. With the peak loads limited to a safe value, it then becomes possible to permit the average load to approach somewhat nearly the continuous capacity of the machine which condition results in load factor betterment. Caution must be exercised, however, not to exceed the limit in this direction since the resistors may be in circuit suffi-

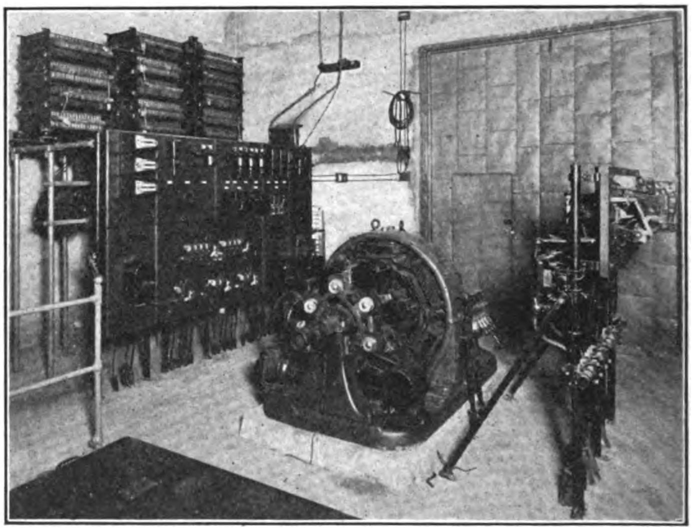

Fig. 5—Interior View of 2000-Kw. 600-Volt Synchronous Converter Substation on Cincinnati Lawrenceburg and Aurora Electric Street Railway

ciently to interfere too greatly with the average trolley voltage, thereby decreasing train speeds as well as incurring an undesirable energy loss from heating in the resistors. Based on this principle as well as the fact that the average heating of transformers is low in the smaller interurban automatic substations due to frequent light-load shut-downs, it has become generally standard practise in these stations to provide transformers having a capacity equal to 80 per

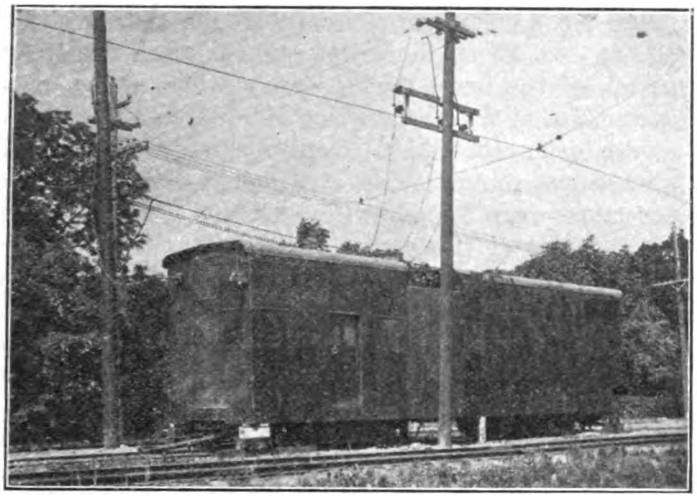

FIG. 6—PORTABLE AUTOMATIC SUBSTATION CONTAINING 500-KW. 600-VOLT SYNCHRONOUS CONVERTER—KANSAS CITY RAILWAYS CO.

cent of the converter rating. In justification of the idea it may be noted that there are in operation at least two railway systems where full advantage of the principle is realized with exceedingly satisfactorily results.

Feeder Saving. Reduction in feeder copper is effected by the application of automatic substation based on the fact that elimination of labor cost in such stations permits a closer spacing and smaller capacity than would be the case with the manually operated type. For the same line characteristics then less feeder copper is required. The installation of automatic stations has in several instances resulted in the removal of sufficient copper to offset materially the cost of the station. Frequently, conditions arise on existing roads when it is necessary to bolster up some particular section of the system due to rapid growth in service requirements. An automatic station is often the cheapest means of producing the desired result since it is more economical to operate than a manual equipment.

Electrolysis. The effects of electrolysis may be to an extent eliminated by the use of automatic substations since their economic spacing is less than those manually operated. Such an arrangement shortens the negative return with a consequent reduction in potential difference between the rail and adjoining water mains. The National Bureau of Standards recognize this benefit in connection with the principle of automatic substation installations.

As previously stated the first automatic installation consisted of devices which with but few exceptions had already been developed by manufacturers for application to other service such as power station, car equipment, steel mill and similar industrial requirements. Experience soon taught, however, that successful automatic substations required an ultra-reliable class of apparatus since the failure of a single device means a shut-down of considerable duration because it necessitates sending a man from some distant point to investigate the trouble. This fact has been realized by the manufacturers and based on experience during recent years a class of apparatus has been developed for these stations which embodies a degree of reliability consistent with the exacting demands of present-day railway service.

Details of Operation. The functions of starting and connecting the machines to the line upon power demand and finally shutting them down after the demand for power has ceased are all carried on in their proper sequence without any assistance whatsoever from an operator. In present day practise the great majority of these stations are controlled entirely by the automatic equipment in accordance with the above statement, but a few are, for specific reasons, remotely controlled by dispatchers with the aid of a pilot wire. A remote controlled station as generally applied may be considered in the same class with a purely automatic station since the control current merely replaces the automatic devices which determine when the station is to start or stop. The remaining apparatus which performs the actual switching operations are identical in both cases.

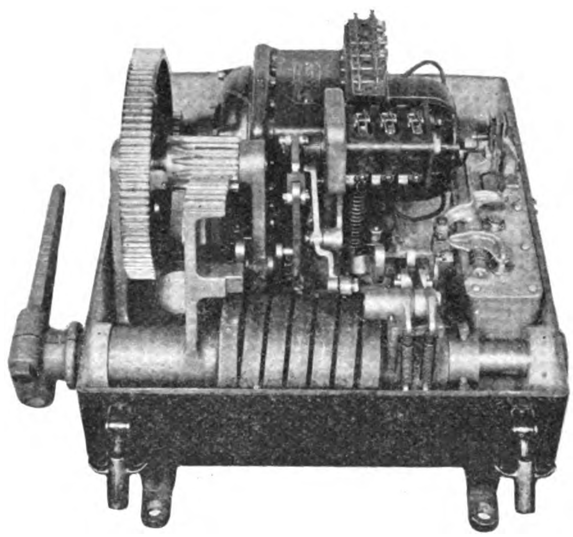

FIG. 7—MOTOR-OPERATED OIL CIRCUIT BREAKER MECHANISM FOR AUTOMATIC SUBSTATIONS

The type of automatic equipments in the most extensive use consists of a group of relays, grid resistors and standard contactors, which together with a motor driven drum controller shown in Fig. 8 perform the usual function of starting, stopping and protecting the machines against irregularities without the aid

of an attendant. In general, relays are used where the functions of starting, stopping and protecting the machines depend upon voltage, current or independent time values. During starting and stopping, however, numerous operations must be performed in a definite sequence, which if not strictly adhered to, is conducive to service interruptions. The motor-driven drum controller is used to obtain this fixed time relation of events and to substitute, wherever possible, a type of contact more substantial than can be used with relays. This device also includes a small d-c. generator which at the proper time during the starting operation separately excites the converter field, thereby definitely and immediately insuring the correct polarity.

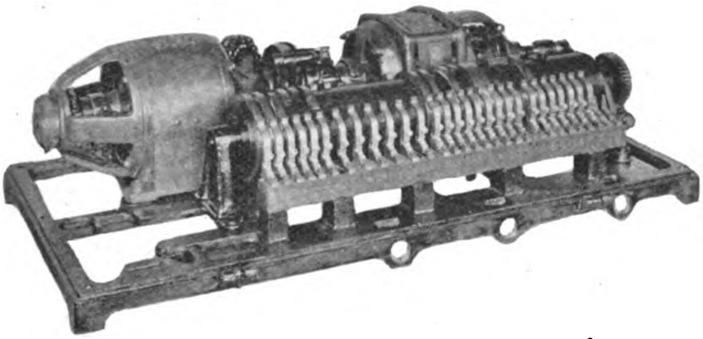

FIG. 8—MOTOR-OPERATED CONTROLLER AND EXCITER FOR AUTOMATIC SUBSTATIONS

Protective devices having the following duties are provided to perform the functions ordinarily left to the discretion of the operator.

1. To limit the overloads.
2. To limit the temperatures.
3. To shut down the machine.
   (a) When a-c. or continuous d-c. short circuits occur.
   (b) Upon failure of alternating current.
   (c) Upon failure of any device.
   (d) In case of excessive speed.
   (e) Upon reversal of direct current.
4. To prevent machine starting.
   (a) During low a-c. voltage.
   (b) During single-phase a-c. supply.

By referring to Fig. 1 which is a typical wiring diagram of an automatic 500-kw., 600-volt equipment, the sequence of operation may be followed. For convenience of reference the principal devices have been numbered or otherwise labeled. It will be noted that the 220-volt a-c. control bus is continuously excited from the control transformer No. 11 and the operating coil of contact-making voltmeter No. 1 is always connected between trolley and ground.

Assuming a particular station is shut down and a train is approaching. As it increases its distance from the next station on the line it will eventually cause the trolley voltage to drop and at a predetermined value, usually 450 volts, contact-making voltmeter No. 1 opens, de-energizing the operating coil of relay No. 2, which had been previously held open by excitation from the 220-volt a-c. control bus through relay No. 1. The closing of No. 2 closes relay No. 3 causing it to pick up and close contactor No. 4 provided the hand reset switch and contacts of a-c. low-voltage relays No. 27 are closed. Relays No. 2 has a dashpot to prevent momentary fluctuation of low voltage from producing false operations of the machine. With the drum controller No. 34 in the "off position" as would be the case before the machine starts, contactor No. 4 completes a circuit through segments No. 13 and No. 16 on the drum controller and the limit switch of the brush-raising device which closes contactor No. 6, thereby starting rotation of the motor-driven drum controller. Controller segment No. 15 soon closes contactor No. 5 which in turn energizes the motor-operated oil switch mechanism causing the main converter transformers to become energized by the closing of oil circuit breaker No. 7. The operating coil connection of contactor No. 5 is then transferred from segment No. 15 to No. 14. This circuit passes through an auxiliary switch on the oil circuit breaker to insure the return of all devices to their normal position should the breaker open for any reason. When segment No. 2 makes contact, starting contactor No. 10 is closed connecting the converter to the low-voltage taps provided the a-c. supply is delivering three-phase current as determined by relay No. 32. Shortly the drum controller stops rotating because of the gap in segment No. 16 and waits if necessary for the converter to come up to speed. At approximately synchronism, speed-control switch No. 13 closes, bridging by aid of segment No. 20 the gap in segment No. 16, causing the controller again to start rotating so as to complete the function of connecting the machine to the line.

Next segment No. 3 closes contactor No. 31 connecting to the converter fields a 250-volt supply obtained from the small generator on the drum controller, thereby immediately ensuring proper polarity. Contactor No. 31 is then opened by segment No. 3 and the self-exciting field contactor No. 14 closed by segment No. 4 and running contactor No. 16 closed by segment No. 5 connecting the converter to normal secondary a-c. voltage. Starting and running contactors No. 10 and No. 16 are both mechanically and electrically interlocked with respect to one another to insure against accidentally short-circuiting a portion of the transformer secondary winding. Segment No. 26 next starts the motor-operated brush rigging causing the converter brushes to be lowered which completes the operation of preparing the machine for connection to the d-c. bus. Segment No. 7 is next energized with 600 volts direct current and shortly thereafter segment No. 8 closes the d-c. line contactor No. 18 whose control circuit is in series with converter field relay No. 30, polarized relay No. 36 and auxiliary switches on running contactor No. 16 and control

contactor No. 4, thereby ensuring before closing No. 18 that the converter has proper polarity, correct field and full voltage a-c. running connections.

As soon as the line contactor closes the machine delivers load to the bus through the load limiting resistors which, however, are soon short-circuited by contactors No. 20 and No. 21 operated by segments No. 9 and No. 10. The drum controller is then stopped by segment No. 17. When connection to the bus is made through No. 18 the flow of current closes relay No. 37, which will cause relay No. 3 to remain closed regardless of relay No. 1 whose function started the station. In other words the control of the station is now dependent on the contacts of No. 37 which will remain closed so long as a predetermined current is being delivered to the bus. Should the current fall below a set value, relay No. 37 will open and cause relay No. 3 to drop out after a certain period of time and shut down the station. Relay No. 3 has a dash-pot and is timed so that momentary low values of current causing No. 37 to open will not shut down the equipment.

When the station does shut down relay No. 3 opens contactor No. 4 causing running contactor No. 16 and d-c. line contactor No. 18 to drop out and disconnect the machine. Contactor No. 5 opens after contactor No. 4 which operation establishes through an auxiliary contact a circuit to contactor No. 6, thereby starting the controller and running it to its "off position." While doing this, however, segment No. 24 trips out the oil circuit breaker and segment No. 25 causes the converter brushes to be raised in preparation for starting upon the next load demand.

The proceeding covers briefly the necessary operations in starting and stopping the machines, but there remains the equally important functions of protecting the equipment from irregularities caused by disturbances on either the a-c. or d-c. side of the station or within the apparatus itself. Briefly these contingencies are taken care of as follows:

In the event a heavy d-c. overload occurs, relay No. 24 will pick up and open contactor No. 20, thereby inserting resistance in the circuit. Should the overload increase to a greater value, relay No. 25 will operate and insert more resistance, and in stations not provided with individual feeder protection a third step of resistance is provided to limit still greater overload demands. The value of resistance used is such as to permit short circuit in the immediate vicinity of the station without injuring the machine. The resistor capacity, which determines the length of time heavy overloads can be carried by the resistors without serious heating, is to a degree a function of the service requirements but the duration of those irregularities cannot be foretold with accuracy and the practise of providing liberal capacity in the resistors has not only proved desirable but very necessary. In some stations individual feeder protection which consists of an overload relay No. 23, a contactor No. 19 and a resistor in each feeder circuit is installed, thereby localizing to a degree the function of overload protection to each feeder. With such an arrangement only two sections of resistance are used in the machine circuit.

Protection from overheating the machine, its bearings and load limiting resistors is obtained by use of temperature relays No. 38 and No. 33 arranged to shut down the station immediately should such a condition arise.

A reversal of direct current is prevented by relay No. 29 and over-speed by speed-limit switch No. 12-A. Both of these devices necessarily operate a control circuit which immediately opens contactor No. 4 and shuts down the station. A shunt-trip hand-operated d-c. circuit breaker No. 15 is in series with No. 18 and only used to protect against the possibility of the line contactor freezing closed. Should this condition occur the converter would motor from the d-c. end upon the a-c. end being disconnected and the excessive speed resulting would trip the circuit breaker No. 15 through the operation of speed switch No. 12.

In case a short circuit occurs on the a-c. side of the equipment, the definite time limit overload relay No. 28 will trip out the main oil circuit breaker, shutting down the station and at the same time opening the hand reset switch which necessitates reclosing by hand before the station can be started again. This feature insures an inspector visiting the station to investigate the cause of the serious a-c. overload.

Low a-c. voltage relay No. 27 which is calibrated for a definite value is connected so as not to permit the station to start or to shut it down if running should the high tension voltage become so low as to interfere with proper operation.

If for any reason a single-phase condition exists on the secondary side of the transformer during starting operations, relay No. 32 will lock out starting contactor No. 10 and prevent the converter from being connected to the transformer.

Polarized relay No. 36 protects against the possibility of the machine ever being connected to the line in the reverse direction. Unless proper polarity has been established before connecting the machine to the bus, line contactor No. 18 will not close.

In stations containing a motor-generator set instead of a synchronous converter, certain modifications to the equipment are necessary to accommodate the starting operations, but the scheme of operation with few exceptions is similar to the converter equipments. Oil-immersed starting and running contactors are used because of the higher transformer secondary voltage and a certain amount of overload protection is obtained by inserting one or two steps of resistance in the generator field circuit in addition to two steps of series resistance in the main d-c. circuit. This arrangement reduces initial cost since the field resist-

ance and its contactors are of small capacity. An energy saving in resistor heat loss is also accomplished. The 250-volt generator on the drum controller becomes unnecessary in the case of a motor-generator automatic equipment.

The recent development of flash barriers for railway machines affords a device of much benefit to automatic substations and these devices are now included by one manufacturer as a regular part of the equipment. Where conditions are particularly severe and much trouble is experienced from flashing, barriers and a quick-acting circuit breaker will absolutely protect the machine.

The recent development in automatic equipments has largely consisted of perfecting and making more reliable the present type of station as well as arranging for and applying the principle in other applications such as lighting, mining and hydraulic generating stations. Among specific instances of improved design may be mentioned the elimination from the equipment of all disk-type interlocks and the substitution of substantial finger-type auxiliary contacts. Relay contacts element have been improved where necessary so as to provide a quick make and break action and on d-c. circuits blow-out coils have been added. An improved type of motor-operating mechanism as shown in Fig. 7 for oil circuit breakers is now in use in which compactness and reliability are the outstanding features. D-c. contactors having a rupturing capacity sufficient to handle any load conditions have been developed and are performing their function with complete success. Reverse current and under-load relays of substantial construction and capable of accurate calibration at low current values have been designed to accommodate the conditions of automatic substation operation.

The use of automatic control in railway substation has in a comparatively short time expanded to where it is firmly established in city and interurban railway operation. The successful experience of the past has resulted in larger capacity stations serving heavy traffic being made automatic. The adaptation of this type of control to electric trunk line service at 2400 or 3000 volts direct current as well as more extended use in the strictly industrial field is not far beyond the horizon.

Short-Circuit Protection for Direct-Current Sub-Stations

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The author includes an outline of the progress made in protection of direct-current machinery from short circuits since the publication of a paper at Atlantic City on this subject.

The improvements mentioned include the refinement and perfection in details of the flash barriers; a new design of high-speed circuit breaker for both direct-current substations and electric locomotives; a new high reluctance commutating pole for 60-cycle synchronous converters and a new design of protected brush holder. An instructive analysis of conditions during direct-current short circuits is shown by several photographs, oscillographs and diagrams. Special reference is made to operating results on the electric zone of the Chicago, Milwaukee and St. Paul Railroad.

THE investigation of means to prevent flashing of direct-current machinery and development of suitable equipment has been continued since the presentation of the paper on "Protection from Flashing for Direct-Current Apparatus," by Mr. J. L. Burnham and the writer at the Atlantic City Convention in 1918.* This paper outlined in a general way the results obtained with quite a number of different methods of reducing or preventing flashing under extreme overload or short-circuit conditions.

This study indicated that a special form of flash barrier with arc coolers and a new form of high-speed breaker with current-limiting resistance had proved the most promising development. Tests showed that the two types of protection provided complete protection from a "dead" short circuit caused by short-circuiting the terminals of a machine without external resistance.

These two types of protection have been further perfected and are now in regular commercial use. They are used either separately or together and in many instances considered standard railway practise.

The improved type of high-speed breaker described has been perfected in all details as shown in Figs. 1 and 2.

Thirteen of these breakers were installed by the Chicago, Milwaukee & St. Paul Railroad as part of the electrification of their Coast and Cascade Divisions. Fig. 2 shows the breaker with the arc chute installed but with covers removed. This view shows the calibrating rheostat used to set tripping point of the breaker. Description of this breaker will not be repeated as general theory of operation and design is described in the paper referred to, and more detailed description of the perfected breaker will be described in article by Mr. J. F. Tritle in the April number of the *General Electric Review*.

*TRANS. XXXVII Part II, 1919, page 1341-1365.

To be presented at Pittsburgh Meeting of the A. I. E. E., March 12, 1920.

This breaker was used instead of the first type of circuit breaker which has given successful operation during the past three years in the fourteen substations of the 440-mile original electrification of the Chicago, Milwaukee & St. Paul Railroad. This new breaker has the advantage of lower cost and greater simplicity.

One of these breakers is used with each of the 2000-kw., 3000-volt, synchronous motor-generator sets in the Tacoma, Renton, Cedar Falls, Hyak and CleElum Substations and the remaining five breakers on each of the new gearless type passenger locomotives. On account of the lower cost of these breakers and advantages of using the "unit" system throughout, each of the sets is protected by its own high-speed breaker instead of one breaker per substation, the arrangement in the original installation.

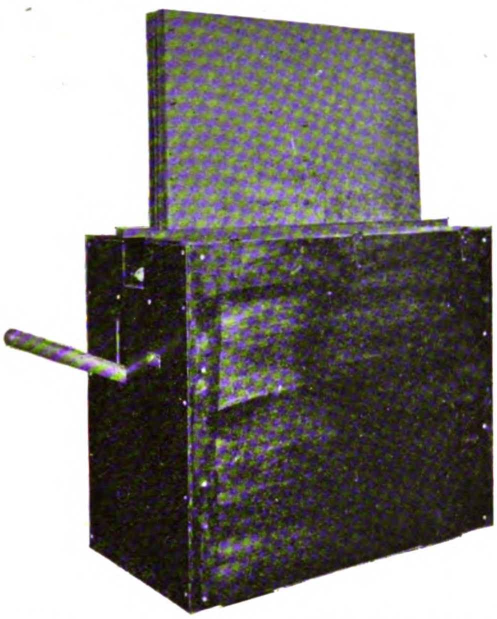

Fig. 1—1500-Ampere, 3000-Volt, D-C. High-Speed Circuit Breaker

The general connections, location of circuit breaker, etc., are shown in Fig. 3.

The circuit breakers for the substations and locomotives are exactly alike with exception of interlocking and calibration for tripping points.

The circuit breakers were given a very exhaustive test in connection with one of the 2000-kw. sets in test before shipment, with very successful operation in all details. It was found that the generators could be short-circuited with only sufficient cable in the circuit to connect the different meter shunts, short-circuiting contactor and high-speed breaker without damaging machine in any way and with practically no flashing at the brushes. Figs. 4 and 5 show photographs of two of these short circuits, one of which gave so slight a flash that it can hardly be seen while the other shows very slight flashing in the flash barriers. Fig. 6 shows oscillogram of one of these short circuits giving a very good idea of the high speed of the breaker and the protection afforded. It will be noted that the current was limited to about 7000 amperes and reduced to three times load in 0.016

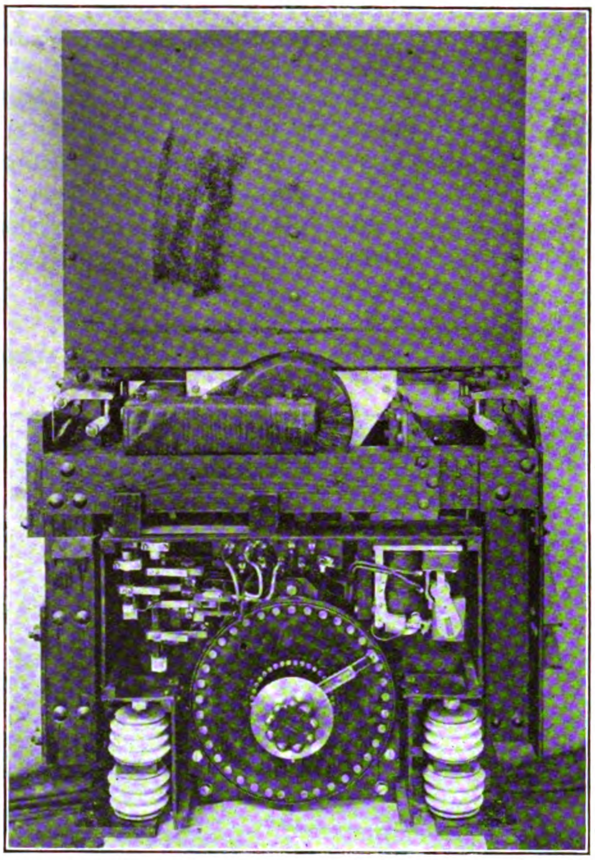

Fig. 2—1500-Ampere, 3000-Volt D-C. High-Speed Circuit Breaker With Asbestos Lumber Casing Removed Showing Rheostat Used to Obtain Different Tripping Points

seconds. The current starts to decrease in 0.0081 of a second and it will be noted that the area representing the load which would be likely to cause flash-over is very small and of such short duration that

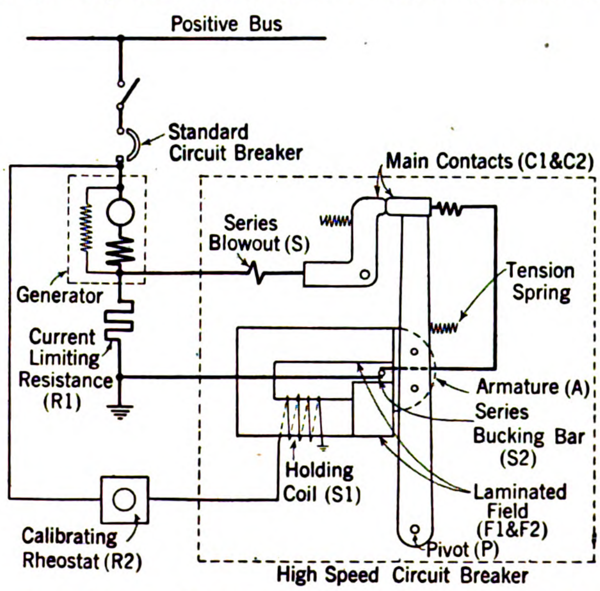

Fig. 3—General Connections of High-Speed Circuit Breaker

very little gas or arc could be formed. Fig. 7 has been prepared to show graphically the much greater protection afforded by circuit breaker of such high speed over that obtained with the usual type of breaker. This figure shows the current curve of a 2000-kw., 3000-volt machine on short circuit when protected by the high-speed breaker and by a standard 3000-volt breaker designed for higher speed than usually obtained with regular carbon-break 600-volt breakers. The area of each curve above the load which would cause flashing has been cross-hatched to show the ratio between the two areas which gives a very good idea of the value of the great speed and the reason there is so little flashing. During these tests about one photograph out of four was similar

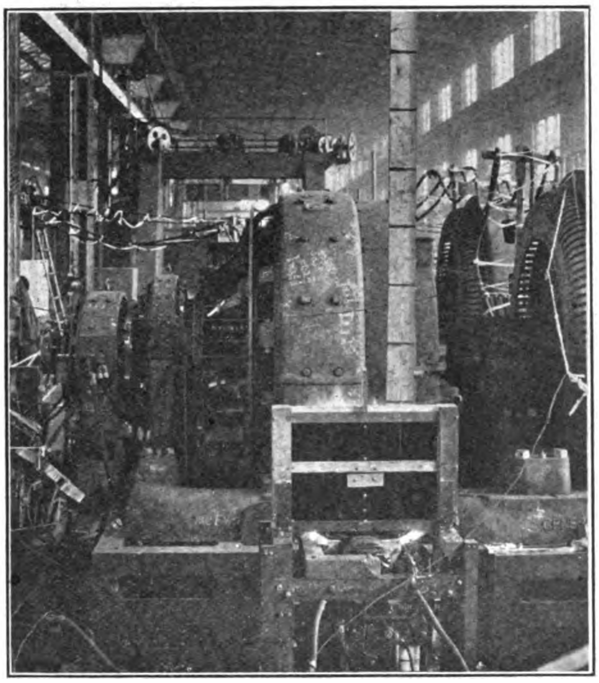

Fig. 4—Short Circuit on 2000-Kw., 3000-Volt Motor-Generator Set Protected by High-Speed Circuit Breaker and Flash Barriers. Tripping Point 2550 Amperes. Line Resistance 0. Current Limiting Resistance 1.2 Ohms

to Fig. 4, while the others were of the character shown in Fig. 5.

A special reliability or endurance test was made as part of the acceptance tests of the breaker during which about 65 short circuits of different magnitude, fifteen of which were "dead" short circuits, were applied at intervals of about 2½ minutes without cleaning the commutators or giving them any attention whatever. At the conclusion of these tests, five "dead" short circuits were thrown on the set within ten minutes. At the end of these tests, commutators were in excellent condition without any need of cleaning or attention of any kind.

These circuit breakers are now in regular operation and reports received of their operation have been very gratifying.

The application of the high-speed circuit breaker to direct-current electric locomotives is another distinct advance as in addition to protecting the apparatus on the locomotive, it prevents the short circuits from affecting the substations.

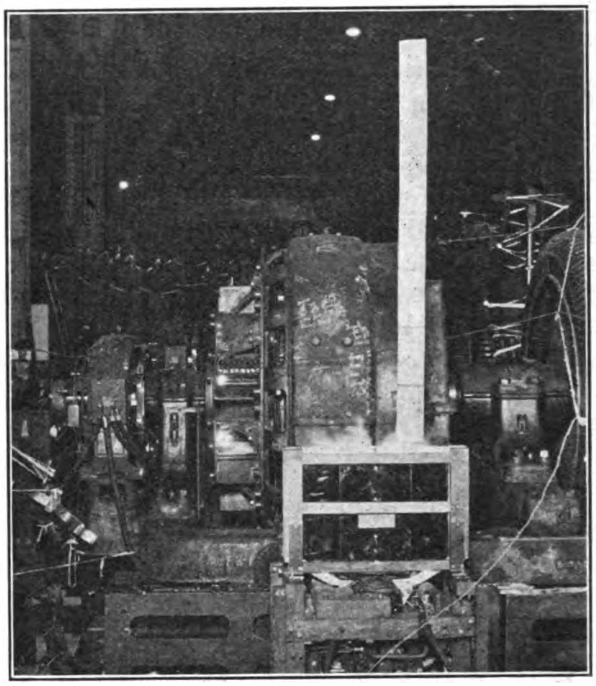

Fig. 5—Short Circuit on 2000-Kw., 3000-Volt Motor-Generator Set Protected by High-Speed Circuit Breaker and Flash Barriers. Tripping Point 2940 Amperes. Line Resistance 0. Current Limiting Resistance 1.2 Ohms

If both the substations and locomotives are equipped with this type of high-speed circuit breaker, current under maximum conditions would never reach a value much greater than 7000 amperes. The value of the

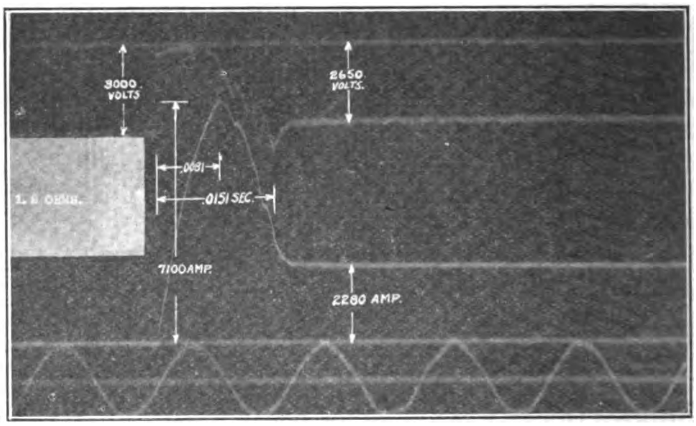

Fig. 6—Short Circuit on 2000-Kw., 3000 Volt Motor-Generator Set Protected by High-Speed Circuit Breaker and Flash Barriers. Tripping Point 2250 Amperes

maximum short-circuit current decreases very rapidly with distance from substation as shown in Fig. 8. These records were taken with a 1500-kw., 3000-volt motor generator set connecting the overhead trolley consisting of two No. 4/0 wires directly to the 100-

lb. track rails and closing the circuit at the substation. It will be noted that the maximum peak current is only 3600 amperes with short circuit 4800 ft. from the substation and 2860 amperes, 9600 ft. from the substation as compared with 7000 amperes "dead" short circuit across the terminals of the machine.

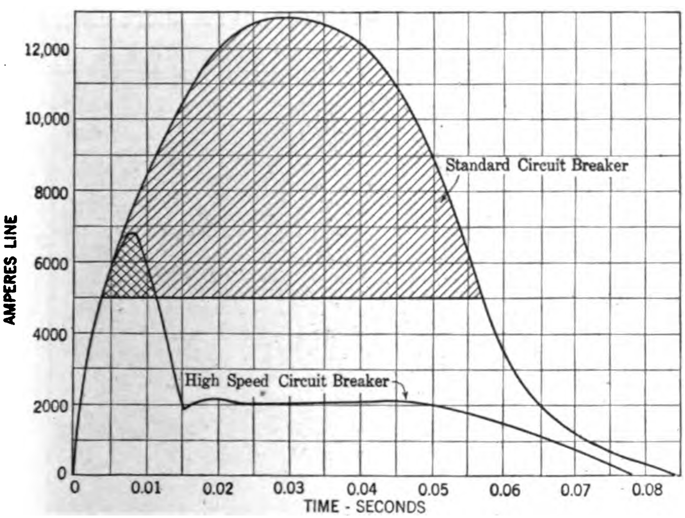

Fig. 7—Short Circuit on 2000-Kw., 3000-Volt Motor-Generator Set Protected by High-Speed Circuit Breaker with Curve Showing Current Which Would be Obtained with Standard Circuit Breaker. Ratio of the Area of the Two Curves Above 5000 Amperes Gives Indication of the Protection Afforded

The value of this type of protection was proved very conclusively during these tests due to the accidental grounding of one of the switchboard busbar insulators. The high-speed breaker inserted the current limiting resistance so quickly that some time was required to locate the trouble as burning at the grounded point was so slight as to be hardly noticeable, indicating that even under such extreme conditions current is reduced so quickly that sufficient time is not allowed to cause current to generate sufficient heat to cause destruction of the current-carrying parts.

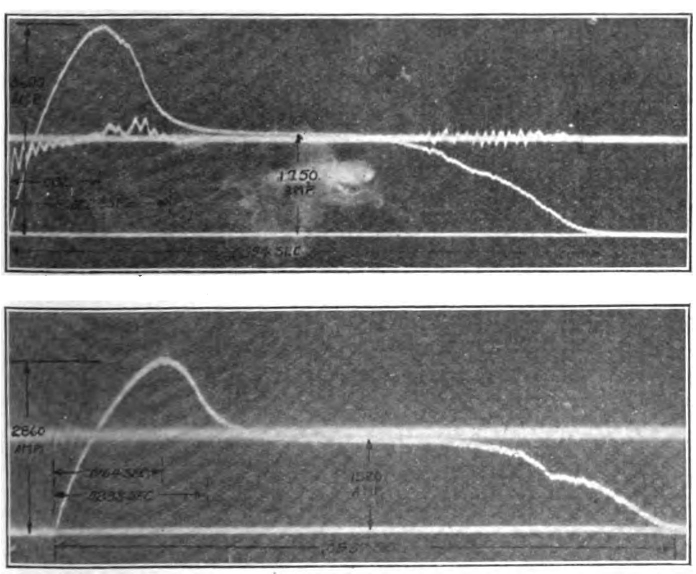

Fig. 8—Short Circuit on 1500-Kw. 3000-Volt Motor-Generator Set at Different Distances from Substation. Generators Protected by High-Speed Circuit Breaker and Flash Barriers

Another of the incidental advantages of this type of protection is the elimination of disturbances on the a-c. side of synchronous converters or motor-generator sets ordinarily caused by d-c. short circuits due to the fact that the load is decreased so quickly that momentum of the armatures supplies the energy and the load is not increased materially on the a-c. side. The overload relays are therefore not affected, increasing very greatly the general operating efficiency of a substation, eliminating time required to start up set from the a-c. side, etc. After the occurrence of a short circuit it is only necessary for the operator to close the high-speed breaker and then the main switchboard breaker which is interlocked with the high-speed breaker after which the main switch is thrown in following regular switching practise. If the short circuit still persists, the high-speed breaker will again open but with no flashing or damage to brushes or commutator and greatly decreased duty on the regular breaker.

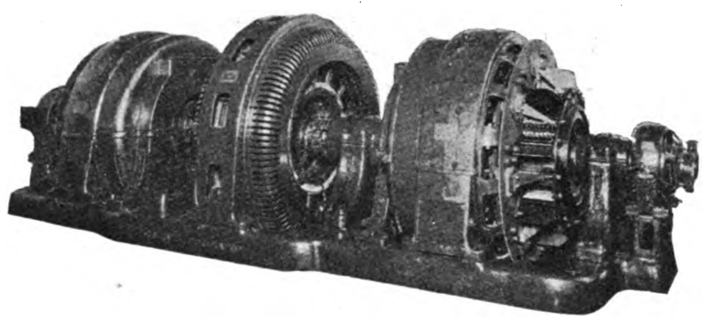

Fig. 9—2000-Kw., 3000-Volt D-C. Synchronous Motor-Generator Set Equipped with Flash Barriers

The flash barriers described in the original paper have not been changed in any essential details, improvements being along the line of simpler construction, ease of removal for inspection and improvement in appearance.

These barriers with iron wire arc coolers are standard equipment on all 3000-volt motor-generator sets as well as on all machines used in connection with automatic substation control. Fig. 9 shows one of the 2000-kw., 3000-volt sets for the Milwaukee electrification equipped with these barriers, while Fig. 10 shows barriers for 600-1200-volt, 60-cycle, 500-kw. synchronous converter.

Flash barriers and high-speed circuit breaker are standard equipment on 1500 to 3000-volt substations and it is believed this practise will be extended to include 600 and 1200-volt apparatus.

Another advance in short-circuit protection is the protected type of brush holder recently perfected as

shown in Fig. 11. This brush rigging is protected on all sides where flashing might occur by asbestos lumber so that an arc cannot readily hold between brush holders of opposite polarity and prevents the formation of iron or copper vapor which might cause a flash to the frame and cause damage to the brush rigging or commutator. A removable cover is provided for inspection and removal of brushes. It is made of an iron sheet for convenience as there has been no tendency for the arc to strike this part of the brush rigging during tests or in actual operation. It will be noted that this type of brush rigging lends itself very readily to the addition of flash barriers as shown in Fig. 10.

This type of brush rigging has been standardized for all 600-volt, 60-cycle synchronous converters.

The use of the high reluctance commutating pole is a very promising improvement which has just been made in 60-cycle, 600-volt synchronous converters

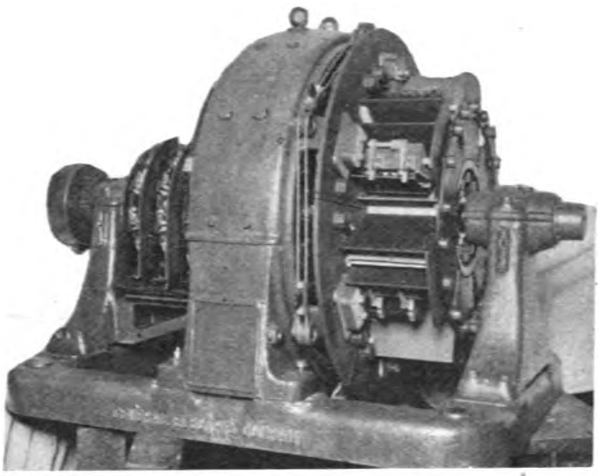

Fig. 10—500-Kw., 600 1200-Volt 60-Cycle Synchronous Converter Equipped with Flash Barriers

and has been standardized for all 60-cycle machines. Tests indicate that the use of these poles raises the flashing point at least 50 per cent. In actual commercial use the improvement is greater than indicated by this figure as a very great proportion of short circuits which originally caused flash-over would not cause flashing on machine equipped with this new type of commutating pole winding.

These improvements are of particular value for 60-cycle converters which are inherently more sensitive than 25-cycle converters.

Brief attention should be called to the great protection afforded by tapping the feeder at some distance from the substation. This is undoubtedly the cheapest type of protection which can be used but cannot be relied upon to prevent flashing over under extreme short circuits. A very slight amount of permanent resistance such as would be given by such an arrangement greatly reduces the number of flash-overs with very little loss of energy or voltage. Under ordinary conditions it is believed that the distance to the first tap need not be greater than 2000 ft. A greater distance than this causes an appreciable loss of energy and drop in voltage. Fig. 12 shows very clearly the great benefit of a small amount of resistance in reducing the maximum possible current on a short circuit.

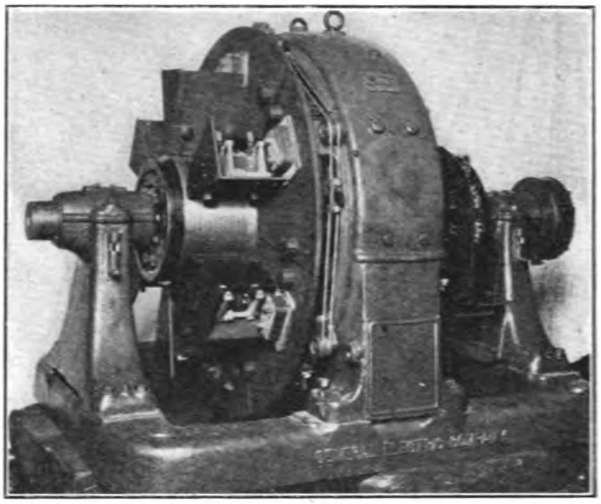

Fig. 11—500-Kw., 600 1200-Volt 60-Cycle Synchronous Converter with Protected Type of Brush Holder

If complete immunity is desired from short circuits, the high-speed circuit breaker and barriers undoubtedly offer the best known solution. With this protection, feeder taps can be connected to the overhead trolley directly at the substations, reducing losses to a minimum. Maintenance on the substation apparatus will also be decreased as burning from short circuits undoubtedly causes most of the wear and deterioration on brushes and commutator. Another particular advantage of this type of protection is that it can be applied to old generators or synchronous converters of any voltage without change in the machine itself.

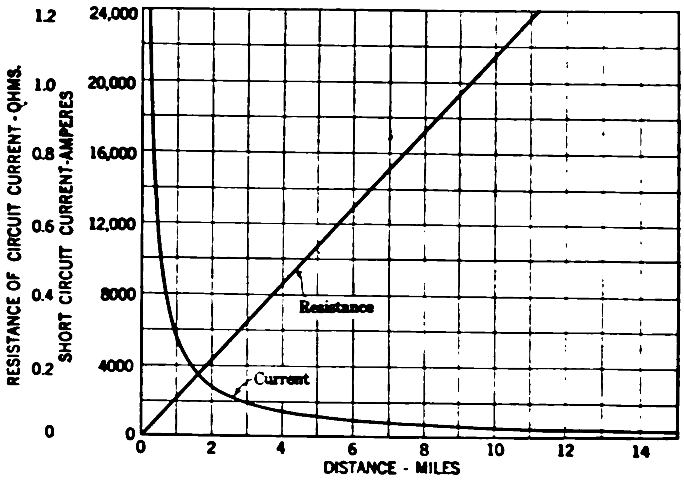

Fig. 12—Curve Showing Ratio of Short-Circuit Current to Distance From Substation

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

INSTITUTE MEETING AT PITTSBURGH

MARCH 12, 1920

On Friday March 12, 1920 the American Institute of Electrical Engineers will hold its 358th Meeting under the auspices, jointly, of the Pittsburgh Section and the Traction and Transportation Committee. The headquarters for the meeting will be the William Penn Hotel. The Board of Directors and the various committees will hold their sessions in the morning. The Board will meet at the Duquesne Club where luncheon will be served. During the morning there will be offered the opportunity to take an inspection trip through the Westinghouse Works concluding with a luncheon to be served to all as guests of the Company. Technical sessions will be held in the afternoon and evening. A subscription dinner will be served in the Ball Room of the William Penn Hotel at 6:15 p. m.

Technical Sessions

2:30 p. m.—Ball Room, William Penn Hotel

1. *Short-Circuit Protection for D-C. Substations* by J. J. Linebaugh, General Electric Company.
2. *Flashing of 60-Cycle Synchronous Converters and Some Suggested Remedies* by Marvin W. Smith, Westinghouse Electric and Manufacturing Co.
3. *Automatic Railway Substations* by Frank W. Peters, General Electric Company.
4. *Automatic Substations for Heavy City-Service* by R. J. Wensley, Westinghouse Electric and Manufacturing Co.

8:00 p. m.—Ball Room, William Penn Hotel

5. *The Two Designs for the Chicago, Milwaukee and St. Paul Locomotives* by W. O. Batchelder, General Electric Company and by N. W. Storer, Westinghouse Electric and Manufacturing Company.

Inspection Trip

On Friday morning there has been arranged an inspection trip through the Works of the Westinghouse Electric and Manufacturing Company at East Pittsburgh. This trip will offer an opportunity to view the new electric locomotives of the Chicago, Milwaukee and St. Paul. Luncheon will be served in the new Cafeteria, said to be the largest in the world, and all are invited to be the guests of the Company.

Train leaves Penn Station, Pittsburgh, at 9:15 a. m. and East Liberty Station at 9:28 a. m. Members from the East, leaving New York Thursday night at 11:30 p. m. should get off at East Pittsburgh. The trip through the Works will start at 10 a. m. and guides will be provided at main entrance to General Office.

Dinner

A subscription dinner will be served in the Ball Room of the William Penn Hotel at 6:15 p. m.

FUTURE A. I. E. E. MEETINGS

Boston, April 9, 1920.—The Boston meeting of the Institute will be held jointly with the American Electrochemical Society and will be under the auspices of the Boston Section and the Committee on Electrochemistry and Electrometallurgy. Tentative plans have been arranged as follows: On Thursday, April 8, the American Electrochemical Society will hold meetings, morning and afternoon at M. I. T., and members of the Institute are cordially invited to attend. On Thursday evening at 8:30 p. m. a Get-together Smoker is planned by the A. E. C. S. at the Copley Plaza Hotel to which all Institute members are invited. On Friday, April 9, a joint session will be held at 9:30 a. m. for the presentation and discussion of a symposium "Electrically Produced Alloys." In the afternoon an inspection trip will be made to the laboratories of the General Electric Company at Lynn where talks on research work at the laboratories will be delivered by Professor Elihu Thompson and others. At 6:30 p. m. a Subscription Dinner will be served at the Copley Plaza at $4.00 per plate. At 8:30 p. m. the evening session will be held at the Copley Plaza where a symposium will be presented on "Power for Electrochemical Purposes." The A. E. C. S. will continue its meetings on Saturday. The plans outlined are subject to change and the final program will be published in the April JOURNAL.

New York, May 21, 1920—Annual business meeting of the Institute. Details to be announced later.

Annual Convention, June 29-July 2. In accordance with the action of the Board of Directors at a meeting held February 18th, and negotiations carried on since, it has been decided to hold the Annual Convention of the Institute at The Greenbrier, White Sulphur Springs, West Virginia, June 29-July 2. This is a week later than it was originally planned to hold the Convention. Details will be announced later.

Pacific Coast Convention, Portland, Ore., July 21-23.—At the meeting of the Board of Directors held February 18th, it was decided, in accordance with the recommendation of Vice-President Fisken and the Portland Section, to hold the 1920 Pacific Coast Convention at Portland, Ore., July 21-23.

Further information will be announced later.

FUTURE SECTION MEETINGS

Cleveland.—March 16, 1920. Subject: "The Vacuum Tube and Some of its Applications." Speaker: Mr. J. W. White, General Electric Company.

April 20, 1920. Subject: "The Sperry Gyroscope." Speaker: Robert B. Lea, Sperry Gyroscope Company.

Schenectady.—March 5, 1920. Subject: "Fly-Wheel Effect for Synchronous Motors Connected to Reciprocating Compressors." Speaker: Mr. R. E. Doherty, A-C. Engg. Dept., General Electric Co., Schenectady, N. Y.

March 19, 1920. Subject: "Power and Transmission." Speaker: Mr. H. H. Dewey, P. & M. Engg. Dept., General Electric Company, Schenectady, N. Y.

PROPOSED FEDERATION OF ENGINEERING PROFESSION

BY CALVERT TOWNLEY

President American Institute of Electrical Engineers

At Lake Placid in June when after full discussion and some amendments you endorsed the report of your Development Committee you took a step of far reaching importance, the effect of which it is difficult to now predict. I refer particularly to that part of the report which deals with the desirability of greater participation in public affairs by the engineer and which recommends that the Institute cooperate with other engineering bodies in an effort to bring this about.

As you have already been advised in the pages of the JOURNAL in compliance with the Convention's desire, your Board of Directors authorized the Development Committee to appoint delegates to a joint conference on this subject with the other Founder Societies and thereupon, throughout the summer, while most organized engineering activities were suspended, your conferees have held frequent meetings with the conferees of the other Societies. Their report was submitted to your Board for the first time at its August meeting and was printed in the PROCEEDINGS. In November your Directors approved the recommendations in this report and instructed your conferees to join with the conferees of such other Societies as might similarly approve the report, in putting into effect the plan there outlined. The report has now been similarly approved by two of the other Societies and therefore the joint conferees are now getting ready to start. Without unnecessary loss of time in all likelihood invitations will be issued to a large number of engineering organizations, both national and local, to send delegates to a meeting at some central point for the purpose of creating a vehicle by which the engineers of the country can unite to consider and to act upon matters of common concern.

When the constitution of the American Institute of Electrical Engineers was adopted its objects were well set forth to be "the advancement of the theory and practise of electrical engineering and of the allied arts and sciences and the maintainence of a high professional standing among its members." It was further wisely provided "that among the means to this end shall be the holding of meetings for the reading and discussion of professional papers, etc." It will be noted that the constitution says "*among* the means provided." It does not say the holding of meetings, and the reading of papers should be the only means employed although for good and sufficient reasons that was practically the only means adopted until a comparatively recent date. When Engineering Council was organized in 1917, a radical move was made. An entirely new activity was started. Council was given broad powers which enabled it to act on matters of common concern without the approval of its sponsors. By participating in the creation of this body the Institute took a long step forward and adopted another means for advancing the theory and practise of electrical engineering and of the allied arts and sciences. But this step, important as it turned out to be, was the act only of your Board of Directors. The members generally did not pass upon it. They knew comparatively little about it. Subsequent events have raised a doubt as to whether even some of the Directors who supported the plan fully understood the extent to which they were delegating authority—much less foresaw how the force of circumstances would oblige Engineering Council to take so active a part in the affairs of the city, state and nation. It is therefore most interesting, not to say extremely gratifying, to those who did sponsor Engineering Council that the membership at large has now very definitely expressed the view not only that this movement should be continued but that it should be expanded far beyond anything previously contemplated.

Presented at the Midwinter Convention of A. I. E. E. New York. February 18, 1920.

It would be premature, not to say hazardous, to say now that if and when delegates from a large number of Societies come together, they will organize and their sponsors will support a Federation such as has been proposed by the Joint Conference Committee but at least the National Societies will have done their duties and if the plan should carry it will place in the hands of a democratic body of engineers chosen from engineering organizations of every kind all over the United States a large measure of authority and responsibility to speak for the engineering profession and to take united action on matters of common concern. It is because of the far reaching character of this prospective step that I have chosen to speak to you about it tonight.

I regard it as one of the most important organization matters which are today before the engineers of the country.

Now if this new national body be created to deal with "matters of common concern," what are they? What are the matters of common concern which engineers in general can deal with better than can our own Institute? Obviously they are not electrical questions—equally obviously they are not questions which specifically and solely concern any one of the other technical branches of the engineering so well cared for by the other national bodies. No one wants, and no one has proposed to interfere in any way with the technical activities or other ordinary proceedings of all the various Societies now existing. The words "Common Concern" are well chosen but they do not convey a definite picture. It is easy but dangerous to deal in generalities, therefore perhaps the best way to indicate the kind of things which a national organization could properly do is to recall some of the things which Engineering Council already has done.

Council was organized during the war and its first activity was to help the Government to find engineers suitable for the many different tasks for which they were sorely needed. The demand was not for engineers of any one branch of the profession. Men were wanted from all branches and the Government had inadequate means of finding them or when found of knowing their qualifications. Engineering Council was peculiarly well equipped to do both these things, and it did them with credit to itself and to the profession, for the country's good and to the satisfaction of the authorities.

Another war activity was likewise cooperation with the Government. This time through the medium of a large Committee which helped pass on the merits on the enormous number of devices, processes, methods and inventions—all of them new and untried, the advocate of each of which was more or less sure that its adoption would settle the contest. It was a sifting committee.

Since the Armistice Council has coordinated and expanded the employment bureau maintained over a period of years by some of the Founder Societies, each dealing with its own members only; as a result of which a larger number of engineers have been placed in positions and a corresponding number of employers served. The Council has conducted and is still conducting an exhaustive examination into the classification and compensation of engineers in Government service—and I do not think it is too optimistic to expect that the Government service will be improved thereby and many much needed adjustments brought about.

Many states have passed and other states are considering the passage of legislation requiring all engineers practising within their borders to be licensed. Engineering Council has been diligently at work collecting and compiling all available data on this material and endeavoring to prepare a uniform law which they might feel justified in recommending wherever such legis-

lation was to be considered. It is not believed that engineers in general are in favor of being licensed, but that is not the question. They already have been licensed in some states, are about to be licensed in others whether they will or no and of course it would be far better to be licensed under a uniform and equitable law with clear definitions, reasonable privileges and no undue burdens than to take whatever may come, which is liable to be more or less of the hit and miss variety.

Engineering Council cooperated with the United States Chamber of Commerce by presenting certain fundamental data on the question of water power and was thanked by that organization for its assistance. In fact, Council's presentation was adopted by a Special Committee of the Chamber, was reprinted and sent verbatim to all the local Chambers in the referendum which the national organization took on this subject. Inasmuch as many of the Chamber's recommendations were embodied in the water power legislation which has now pa sed both the House and the Senate, engineers may feel with satisfaction that at least they contributed toward a useful change in these laws which should have a most beneficial effect.

Engineering Council has testified before Federal authorities on many different subjects, always endeavoring to confine itself to matters which deal with fundamental engineering facts which are beyond the field of controversy and to keep away from political and other questions about which differences of opinion exist among its constituents.

The things that I have enumerated are illustrations. They are by no means intended to include everything that Engineering Council has done. They are each and every one useful acts, acts which could and should be done by engineers but which no one Society could do alone and for which therefore a national body speaking for a united profession is very essential. It will be noted that very few matters have been continued activities. They were done once and then attention was directed to something else. In the nature of the case this must always be largely so and therefore the necessity of putting strong men into office of the National Engineering body, men on whose judgment engineers can rely and who may be counted upon to have the courage of their convictions both to act when necessary and to refuse to act the great many more times when matters beyond the purview of their organization are proposed. Therefore also the necessity for authority to act without reference to the supporting bodies for approval.

One of the fundamental features of the plan prepared by your Development Committee and which also appears in that adopted by the Joint Conferees is that the new national organization shall be composed of delegates from existing engineerng bodies. It will not be a new Society composed of individual members. Such a plan was given exhaustive consideration by the conferees and in the end decisively rejected. The rejected plan has not been without its advocates. They urged with much sincerity and not without reason that it would be a very fine thing if all the engineers of the country—perhaps a quarter of a million strong—could unite in one great big organization to deal with non-technical matters, public affairs and, to look after the engineers' human interest. As this was a fundamental question on which a decision had to be made at the very start and before any other steps could be taken and as it was very thoroughly debated both in your Development Committee and by the Joint Conferees, the membership at large should know the arguments pro and con and form their own opinions; therefore I feel justified in dealing with it tonight.

I am fond of quoting Prof. George Swain's comparison of the Engineer and the Idealist because he has stated an important truth more clearly than I have ever heard it stated before. The Engineer, says Swain, approaches a problem with an open mind. He first obtains all the facts available, then bases his conclusions thereon and proceeds to act accordingly. The idealist on the contrary first pictures the ideal result which he would like to achieve and then pursues that picture, subordinating logic, argument and even facts to his desire. The idealist therefore is a most dangerous citizen. The more perfect his ideal picture, the more dangerous he is and he further attracts support because of his sincerity.

What are the facts in the present case?. They are that in spite of all the efforts put into organization since the beginning, over half the engineers of the country belong to no engineering organizations at all. Those that do are not in one but in many —perhaps 600 Societies—each one created for a specific purpose and having therefore a particular attraction for a certain class of men. To believe that all engineers, or even the joining part of them could ever be corralled into a single Society one would have to have confidence, that he was better able to devise such a Society than any or all of his predecessors in the profession. The Institute, wisely as it has been managed and rapidly as it has grown, has not been able even to cover the technical side of the entire electric field. There have been a number of vigorous offshoots. If any one could imagine all engineers of every branch put together into one Society of any kind for any purpose—how long would they stay there? It would be human nature to split off—history supplies numberless supporting examples. In the light of the foregoing and for other less fundamental reasons as well, the conferees concluded that it would be far better to try to enlist the support of the large number of growing concerns with a membership aggregating perhaps 100,000 men and without abridging any of their present prerogatives, rather than to start all over again and try to build up a new kind of Society with a new membership and which in addition to the tremendous amount of time, effort and money required might expect to encounter the indifference, perhaps suspicion and in some cases the antagonism of the existing organizations. The primary objection to this plan is that the work of the new organization is to be quite different from that in which most of the old organizations have been engaged. Instead of dealing in the main directly with technical or inter-organization matter it will deal more largely with public affairs, and as the existing societies are not organized for this purpose, and in fact have not only not done it but have in some instances shown opposition to the idea, they should not be relied upon to back it now but on the contrary an entirely new body should be created, one that is not hampered or shackled in any way. The answer to this argument is that while the existing societies were not organized for the kind of work now contemplated several local affiliations of them have been functioning around many of the sorts of work proposed for a number of years and doing it very well, and that Engineering Council has already proved its efficiency and only needed a larger appropriation and the more representative membership to be afforded by the new plan to have occupied a much wider field.

Another basic question is that of finance. Nothing can be done without money. It needs no argument to prove that if the engineers of the country undertake this new activity they must pay its cost. There is no doubt that willing men will be found to devote their services to any good cause under the banner of their profession. That has been demonstrated over and over again, but money is needed as well, and the amount of work accomplished is largely measured by the funds available. The conferees all recognized this fact without argument, the only question to be discussed being how much money must be provided and how is it to be raised? I do not purpose discussing the details of this question except to say that as it is impossible in advance to prepare, much less to defend any very liberal budget because no definite expenditures can be allocated, and also for the reason that when the invitations are first presented to the various Societies very many of them will not be able to make large appropriations; so the conferees concluded that the modest figures used in their report were both a minimum limit and all that they should specify. Later on if the organization is formed and has a chance to demonstrate its value the

engineers of the nation will have ample information on which to alter the dues if they see fit.

The only other comment which I feel should be made is a word of caution and is born of my experience while serving the Institute on Engineering Council. That body has been beset on all sides to advocate or to oppose legislation and while it has not hesitated to do so when the questions involved were of a nature where the advice of engineers would be of particular value, it has steadfastly declined to become involved otherwise. Bearing this fact in mind my word of caution is against any policy which will cheapen the engineer. Our collective advice is valuable on subjects with which we are qualified by experience and training to deal and so long as we confine ourselves to such subjects and present a united front our influence can and will be considerable. But the minute we digress and begin to deal with matters outside the purview of engineering and subjects closely allied thereto, we sacrifice our preferred position and have no more claim to be heard than any body of educated citizens of similar numbers. We also would then almost certainly make the very serious mistake of misrepresenting our membership because while engineers can be safely counted upon to agree on fundamental facts they are of all shades of political belief and have as many different views as any one else regarding other questions. My word of caution therefore is really a plea to you to give this side of the subject your due thought and to make your views known at all proper times and places.

The work of any body of representatives depends on that of its constituents and the movement to create a national organization will be successful only to the extent that it is able to enlist the support of the individual members of the profession. I hope and expect to see the members of the American Institute of Electrical Engineers do their duty in this respect as they have always done it in connection with every task that has been put up to them in the past. I realize that much of what I have said to you is a repetition of what you already know but my excuse is that I regard the subject of so great importance to engineers as to bear repetition—not once but many times, and my desire to impress upon you that the future success of the plan is your problem and on you and your colleagues in other branches of engineering will depend its fate.

CONFERENCE OF ENGINEERING SOCIETIES

A conference of the governing bodies of its Member Societies called by Engineering Council, was held January 23 in Engineering Societies Building, New York, to discuss relations of Engineering Council and the bodies which it represents, to the engineering profession. The societies represented at the conference were the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Society for Testing Materials, and the United Engineering Society.

A discussion of the organization and work of Engineering Council was entered into thoroughly, and the financial conditions were discussed with a view to providing permanent financial support for Council or its successor. The recommendations of the Joint Conference Committee of the Development Committees of the Founder Societies were outlined; and the Conference Committee's plan, to bring into existence the comprehensive organization which it has proposed, was endorsed.

The meeting lasted all day and was harmonious and constructive, the spirit of cooperation being predominant. To make a federation of the entire engineering profession to carry on civic and other non-technical activities for the several societies, to centralize responsibilities, and still keep it a truly nation-wide movement, was clearly a problem, yet one which was felt could be carried to a successful and helpful solution, by forming an organization, broad in purpose and widely affiliated.

The discussions resulted in the adoption of several resolutions, it being understood that these actions were in the nature of recommendations to the societies. These included recommendations relating to the financing of Engineering Council pending the formation of the more inclusive affiliation of national and local engineering organizations. The endorsement of the Conference Committee's proposed plan for the affiliation of the Engineering Profession was expressed in the following resolution:

WHEREAS, this Conference of national engineering societies has considered the recommendations of the Joint Conference Committee of the four Founder Societies, therefore, be it

RESOLVED, that the Conference adopts in principle that report and requests the joint Conference Committee to call, without delay, a conference of representatives of national, local, state, and regional engineering organizations to bring into existence the comprehensive organization proposed.

The Conference Committee's plans and the method by which these plans were formulated, together with many of the considerations involved in this comprehensive movement, with an outline of what it connotes for the engineering profession, is set forth in detail in the admirable address of President Townley as printed above.

MIDWINTER CONVENTION

The Institute held its Eighth Annual Midwinter Convention, February 18 to 20, 1920 in the Engineering Societies Building, 33 West 39th Street, New York. The total attendance of members and guests was about 1100.

Wednesday Afternoon

On Wednesday afternoon, February 18th, over 260 members and guests took advantage of the Western Electric Company's invitation to visit the Bell System Laboratories. They were divided into groups under the leadership of guides thoroughly familiar with the equipment of the various laboratories.

During the three days of the Convention many members visited the principal power stations and other places of engineering interest in New York in accordance with arrangements which had been made by the Excursions Committee, consisting of Messrs. W. S. Finlay, Jr., chairman, Philip Torchio, N. A. Carle, W. G. Carlton, Preston S. Millar, Frank W. Smith and L. F. Morehouse.

The Wednesday evening session was called to order at 8.15 p.m. by President Calvert Townley who delivered an extremely interesting address on "Proposed Federation of Engineering Profession." The address is printed in full elsewhere in this issue. President Townley then called on Preston S. Millar, Manager Electrical Testing Laboratories who presented his paper on "Daylight Saving." He was followed by W. S. Gorsuch and E. J. Cheney who presented their respective papers on "Essential Statistics for the Comparison of Steam Power Plant Performance" and "Standard Graphic Symbols." This discussion which followed was participated in by the following men: D. McF. Moore, H. R. Summerhayes, C. R. Underhill, E. H. Martindale, R. S. Hale, A. B. Smith, W. I. Slichter, E. J. Cheney, Selby Haar, P. G. Agnew, Louis M. Meckler, Jr., Alexander Maxwell, O. C. Traver, and closure by the respective authors.

Thursday Morning

The second technical session was opened at 10.30 a.m. Thursday morning with W. S. Murray acting as Chairman. The subject of this session "Economical Supply of Electric Power for the Industries and the Railroads of the Northeast Atlantic Seaboard" was arranged in the form of a symposium. Mr. Murray's very complete presentation of the subject was followed by presentations by Malcolm Maclaren, Henry G. Reist, Charles F. Scott, Percy H. Thomas, N. W. Storer, Philip Torchio, S. T. Dodd, David B. Rushmore, Arthur O. Austin, E. E. F. Creighton, H. W. Buck and John W. Lieb.

The following resolution was offered by Mr. H. W. Buck:

Moved: That it is the sense of this meeting to recommend to the Board of Directors of this Institute to appoint a Committee, of which Mr. Murray shall be Chairman, to carry alongthis most excellent movement which he has initiated today.

Thursday Afternoon

On Thursday afternoon parallel technical sessions were held in the Auditorium and in one of the 5th Floor Rooms. At the 5th Floor session, Dr. Clayton, H. Sharp presided as Chairman. The first paper entitled "A Method of Separating No-Load Losses in Electrical Machinery" presented by the author, C. J. Fechheimer, was discussed by V. Karapetoff, W. F. Dawson and W. S. Slichter. The second paper of the session entitled "Inherent Regulation of D-C. Circuits" by A. L. Ellis and B. W. St. Clair was read by Mr. Ellis and discussed by V. Karapetoff, H. R. Summerhayes and L. W. Thompson. The last paper entitled "Measurements of Projectile Velocities" by P. E. Klopsteg and A. L. Loomis was presented by Mr. Klopsteg and discussed by E. E. F. Creighton and Roy Kegerreis.

At the Auditorium session Donald McNicol presided as Chairman. The first paper, read by the author J. H. Bell on "Printing Telegraph Systems" was discussed by George O. Squier, Edgar Russell, C. E. Davis, H. A. Emmons, P. M. Rainey, J. P. Edwards, E. R. Shute, R. E. Chetwood, D. Benjamin and John H. Cuntz.

The second paper on "Maximum Output Networks for Telephone Substations and Repeater Circuits" by G. A. Campbell and R. M. Foster was presented by Mr. Campbell and discussed by Lloyd Espenschied and O. B. Blackwell.

Thursday Evening

About 375 members and guests attended a Dinner-Dance at the Hotel Astor. This event, which has been a regular feature of Midwinter Conventions for several years past, was exceedingly enjoyable to all present and reflected great credit upon the Committee in charge, consisting of, Messrs. H. A. Pratt, Chairman, N. A. Carle, R. F. Jacobus, R. L. Jones, H. B. Logan E. W. Loomis, W. T. Morrison, F. A. Muschenheim.

Friday Morning

At Friday morning session, 10.30 a.m. S. G. Rhodes presided and three technical papers were presented the first on "A New Form of Vibration Galvanometer" was read by the author, P. G. Agnew and discussed by J. B. Whitehead, C. H. Sharp, W. H. Pratt and P. E. Klopsteg.

The second paper by T. R. Harrison and P. D. Foote on "Precision Galvanometer for Measuring Thermo E. M. F's." was read by H. B. Brooks and discussed by J. B. Whitehead, A. E. Kennelly, W. D. A. Peaslee, E. M. Hewlett and C. H. Sharp.

The third and last paper of the morning session "Notes on Synchronous Commutators" by J. B. Whitehead and T. Isshiki was read by Dr. Whitehead and discussed by P. G. Agnew, E. D. Doyle, A. E. Kennelly and J. H. Morecroft.

Friday Afternoon

On Friday afternoon, 2.30 p.m., S. G. Rhodes presided and called for the presentation of two papers. The first by A. E. Kennelly, R. N. Hunter and A. A. Prior on "Oscillographs and Their Tests" was presented by Dr. Kennelly and discussed by F. S. Dellenbaugh, R. N. Hunter, B. W. St. Clair and N. E. Bonn.

The second paper by H. B. Brooks on "The Accuracy of Commercial Measurements" was read by the author and discussed by W. H. Pratt, J. S. Craighead, E. P. Peck, F. V. Magalhaes, F. H. Baumann, Alexander Maxwell, H. H. Sticht, B. W. St. Clair, A. L. Ellis and Harvey P. Sleeper.

A. I. E. E. DIRECTORS MEETING

FEBRUARY 18, 1920

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Wednesday, February 18, 1920, at 10:30 a. m.

There were present: President Calvert Townley, New York; Past President C. A. Adams, New York; Vice-Presidents C. E. Skinner, Pittsburgh, N. A. Carle, Newark, N. J., Wills Maclachlan, Toronto; Managers Charles S. Ruffner, Wm. A. Del Mar, W. I. Slichter, L. F. Morehouse, New York, Charles Robbins, Wilfred Sykes, Pittsburgh, E. H. Martindale, Cleveland, Walter A. Hall, West Lynn, Mass., L. E. Imlay, Niagara Falls; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

Upon the recommendation of the Finance Committee, monthly bills amounting to $15,682.97 were approved.

Upon the recommendation of the committee appointed to consider the time and place of the Annual Convention for 1920, the Board voted to hold the Convention at the Greenbrier, White Sulphur Springs, W. Va., June 29 to July 2.

A communication was presented from Vice-President Fisken relating to the Pacific Coast Convention of 1920; and upon its recommendation it was voted that the Pacific Coast Convention for 1920 be held at Portland, Oregon, July 21-23.

A report was presented of a meeting of the Board of Examiners held February 16, 1920; and upon the recommendation of the Board the following action was taken upon pending applications: 186 Students were ordered enrolled; 141 applicants were elected to the grade of Associate; 6 applicants were elected to the grade of Member; 12 applicants were transferred to the grade of Member; 2 applicants were transferred to the grade of Fellow.

President Townley announced the appointment of the following as members of the Tellers Committee, to canvass and report upon the nomination and election ballots in connection with the coming election of officers of the Institute: Messrs. Edward J. K. Mason, Chairman, W. P. Abendroth, Charles M. Fulk, P. Norton, and P. C. Paquette.

Upon the recommendation of the Chairman of the Sections Committee, a request for authority to organize a Section of the Institute at Worcester, Mass., was granted.

At the request of the American Engineering Standards Committee, the Board approved the admission of the National Safety Council and the Fire Group as members of the American Engineering Standards Committee.

It was voted that the next meeting of the Board of Directors be held at the Duquesne Club, Pittsburgh, March 12, at 10:30 a. m. As announced elsewhere in this issue, a meeting of the Institute will be held in Pittsburgh on the same date.

In addition to these routine actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the JOURNAL under suitable headings.

GENERAL ENGINEERING CONGRESS AT BATAVIA, JAVA, MAY 1920

The Institute has just received through the Director, Bureau of Foreign and Domestic Commerce, Dept. of Commerce notice of a General Engineering Congress to be held at Batavia, Java in May 1920. Two languages, namely: English and Dutch will be employed during the Congress and all publications will be published in both languages. The official opening of the Congress will take place at 7 p. m. May 8th and the program embodying regular sessions, excursions, dinners, etc. will extend to Saturday May 15.

The Secretary of the Institute will be glad to receive the names of any members who expect to attend this Congress.

UNITED ENGINEERING SOCIETY

EXTRACTS FROM REPORT OF TREASURER FOR CALENDAR YEAR 1919

The Surplus Account on December 31, 1918 showed a balance of $5,533.43. This amount has been increased by the surplus from the operating accounts during the year of $9,557.28 making a total on December 31, 1919 of $15,090.71. Of this amount $10,000.00 has been transferred to Depreciation and Renewal Fund, leaving a balance in Surplus Account of $5,090.71.

The Gross Operating Expenses for the year 1919 were $66,812.89, as compared with $66,505.57 for the year 1918, an increase of $307.32.

The funds available for the Library Board, and spent under its direction during the year, amounted to $23,876.64.

The funds available for Engineering Council, and spent under its direction during the year, amounted to $49,012.38, of which $940.07 remained unexpended.

The General Reserve Fund of $10,000 created by the Board of Trustees at a meeting held November 18, 1914 to be available to take care of unforeseen fluctuations of income and outlay, has been preserved intact, there arising no calls on this fund during the year 1919.

The Depreciation & Renewal Fund at the beginning of the year 1919 amounted to $86,163.78. During the year this fund has been increased by the sum of $4,035.22 for interest earned by the investments for this fund and by $10,000.00 added from the surplus at the end of the year, making a total of $100,199.00 on December 31, 1919.

In accordance with the authorization of the Board of Trustees, February 27, 1919, the sum of $13,000.00 was invested in Government of United Kingdom of Great Britain and Ireland, 20 year bonds, 5½'s due February 1937. $5,000.00 being reinvestment of proceeds from Bethlehem Steel Co., 2 year Sec. Gold Notes matured February 15, 1919 and $8,000.00 cash transferred from Surplus to Depreciation and Renewal Fund.

The following summary shows the amounts of the funds held by U. E. S. as of December 31, 1919:

Depreciation and Renewal Fund December 31, 1918	$86,163.78
Interest on invested funds during the year 1919	4,035.22
Transfer for the year 1919	10,000.00
Total	$100,199.00
General Reserve Fund	10,000.00
Engineering Foundation Fund	303,374.80
Library Endowment Fund	102,559.70
Total	$516,133.50

Treasurer's Receipts and Payments, Year of 1919

Receipts

Cash on hand January 1, 1919		$12,869.60
From Founder and Associate societies:		
For office, storage, halls, telephone, & Misc	$76,984.08	
From Societies not in building,		
For Halls	5,727.70	
" Miscellaneous	658.57	
For Library	15,737.42	
" Library Service Bureau	17,740.65	
" Library Recataloging	5,624.99	
" Engineering Council	46,958.91	
Interest collected on Bonds & Deposits	9,640.75	
Interest collected on Engineering Foundation Bonds	15,324.24	
Maturing of $5,000.00 Bethlehem Steel Corp. Bonds	5,000.00	
From A. I. M. E.		
For Building addition	2,500.00	
From A. I. E. E.		
For Building addition	2,500.00	
		204,397.31
Grand Total		$217,266.91

Payments

To Engineering Foundation,		
Income from investments, less collection charges	$15,331.74	
For Govt. of Great Britain & Ireland Bonds purchased	13,169.72	
For Building Operating Expenses	75,350.56	
" Library	24,209.99	
" Library Service Bureau	17,459.33	
" Library Recataloging	4,361.31	
" Engineering Council	49,630.48	
" A. S. M. E. Notes	5,000.00	
" A. S. M. E. Interest on Notes	108.49	
" Collect charges and exchanges	108.11	
Total Payments		$204,729.73
Cash on hand Dec. 31, 1919		$12,537.18
Grand Total		$217,266.91

Assets and Liabilities
December 31, 1919

Assets

Real Estate	$1,947,171.16	
Investments—Foundation	303,321.25	
Library	102,297.50	
General	93,894.72	
Cash	12,637.18	
Accrued Interest Receivable	2,806.88	
Bills Receivable	7,500.00	
Accounts Receivable	8,742.43	
Advances to Library Board	2,602.36	$2,480,973.48

Liabilities

Founders Equity in Property	$1,947,171.18	
Due to General Reserve Fund	10,000.00	
" " Dep. & Renewal Fund	100,199.00	
" " Eng. Foundation Fund	303,374.80	
" " Library Endowment	102,559.70	
Bills Payable	7,500.00	
Library cataloging unexpended balance	1,472.01	
Library Service Bureau unexpended balance	2,666.03	
Engineering Council unexpended balance	940.07	
Surplus December 31, 1919	5,090.71	$2,480,973.48

ANNUAL DINNER OF BOSTON ENGINEERS

The 11th Annual Dinner of The Engineers of Boston and Vicinity will be held on Tuesday evening March 30th, in the main auditorium of The Boston City Club, dinner at 6.15: addresses 7:45. The principle speakers and their subjects will be, Paul D. Cravath, "Some Economic Aspects of the Treaty at Paris;" Dean Roscoe Pound, "Social Engineering." Paul D. Cravath, Attorney, New York City, was one of the American Representatives at Paris during the War. Dean Roscoe Pound is Dean of the Law School of Harvard University, Cambridge, Mass. The dinner is under the auspices of The Boston Section A. I. E. E. and A. S. M. E. and the Boston Society of Civil Engineers. It is, however, open without further invitation to members of any other societies and in fact anyone interested in the engineering profession whether society member or not. Tickets $3.75, obtainable from Ira Cushing, 84 State St., Boston, Mass.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

EXTRACTS FROM ANNUAL REPORT FOR YEAR ENDING FEBRUARY 1920

Engineering Council has completed its third year, continuing work previously started and taking up many new projects. During this past year it has been impracticable for the Secretary to make more than a few visits to engineering societies, and they were to those relatively near New York. The combination of duties for United Engineering Society, Engineering Foundation and Council, together with lack of funds, prevented further visits. Nevertheless, many personal visits on behalf of Engineering Council have been made to groups of engineers from coast to coast by the Chairman; by Representatives Baker, Cooley, Hollis, Loweth, Moore, Skinner and Townley; by Chairman Leighton, of the National Service Committee; and by Secretaries Stoughton and Rice, of the Mining and of the Mechanical Engineers. Several local societies, by letter or personal representative, have requested and received advice and other assistance from Council's office.

The American Society for Testing Materials completed qualifications as the fifth member society, in February, and has since taken an active part in Council's work.

Council held five meetings during the year: three in New York, one in Chicago, in April, and one in Washington, in June. The total expenditures for the calendar year 1919 were $49,000, including $25,000, advanced by the Chairman for the expenses of the Washington office, opened January 1, 1919.

In April, Engineering Council called together in Chicago, representatives of seventy-four technical organizations having 105,000 members, to discuss an effort to secure a National Department of Public Works. To conduct and finance this movement there was created a body now known as the National Public Works Department Association. Branch organizations have been established in most of the States and work has been directed chiefly from Council's Washington office. In September Engineering Council became a member of the Chamber of Commerce, U. S. A.

In January, 1919, by public hearing Engineering Council aided the reinstatement of 350 engineers unfairly dismissed by the City of New York. It also assisted late in the year in securing better salaries for these and other engineers and in preventing a recurrence of last year's unfortunate conditions.

Late in 1919, and in January, 1920, committees were appointed on types of Government Contracts, on Military Affairs, on Co-operation with the American Institute of Architects, and on co-operation with Association of Russian Engineers in America. In response to request, special assistance was given the Signal Corps, U. S. Army, in connection with bills before Congress.

Other notable events in the year's history are: Council took part in organizing a National Board for Jurisdictional Awards in the Building Industries, and has a member thereon. Council appointed three representatives to co-operate with equal numbers from the American Institute of Architects and the Associated General Contractors of America, to determine a policy regarding "Payment for Estimating."

To the Reconstruction Commission of the State of New York, a special committee of engineers, appointed by Council, gave assistance in preparing a Report on Retrenchment and Reorganization in the State Government. On a National Budget System, Council presented testimony through four delegates sent to Washington on invitation of the Select Committee of the House of Representatives. Council gave much assistance to the War Department Claims Board in securing technical experts to review reports on claims amounting to approximately two billion dollars. To expedite completion of topographical maps of the United States, President Wilson, in response to a communication from Engineering Council, by Executive Order, constituted a Board of Surveys and Maps, of one representative each from the fourteen map-making agencies of the Government, and invited representatives of Engineering Council and engineering and scientific societies to cooperate. The new board set up a permanent organization January 13, 1920.

Engineering Societies Employment Bureau, organized immediately after the Armistice was maintained throughout the year. It registered 5400 engineers, the majority of whom had been in Military or Naval Service, and aided a large proportion to find positions. It rendered service to both employers and employees without charge, but at a cost to the Founder Societies of more than $16,000. The Secretaries of the Founder Societies were the Board of Directors. At the end of the year, the Bureau was detached from Engineering Council by actions of the Founder Societies.

A Committee on Classification and Compensation of Engineers, created in March, worked in three sections dealing with engineers in the employment of (1) Federal Government, (2) Railways, (3) Cities and States. (See February JOURNAL; also elsewhere in this issue).

The Committee on Licensing Engineers, after fourteen months' work, presented in December, a valuable report accompanied by a "Recommended Uniform Registration Law, to regulate the practise of professional engineering, architecture and land surveying."(See February JOURNAL.)

The Fuel Conservation Committee continued co-operation with the Government, and recommended support of a Federal appropriation for a survey to determine the desirability of a superpower system in the industrial region extending from Boston to Washington.

The Water Conservation Committee appointed correspondents in twenty-seven States, is seeking correspondents in other States, is collecting useful information, and is aiding the Maine Water Power Commission on questions of policy in response to a request from its chief engineer.

Through its committees and its officers, Engineering Council has considered and acted upon many other matters. Its labors, some of which have been in progress for a long time, are bearing good fruit. As these results become known throughout the country, Council's faithful, quiet work is coming to be better understood and more highly appreciated. Many written and spoken words of commendation have been received. Council is better established than ever before, is known and recognized in governmental circles and has more clearly determined the kinds of work desired of such a joint organization by the engineering societies. Its usefulness has been limited by insuffici-

ency of publicity, but it has had small resources for developing suitable agencies; it has been dependent largely upon its member societies and upon willing but uncertain voluntary services.

Council believes that it has done much good work; it has proceeded carefully in an endeavor to build lastingly. Its future is entirely in the hands of its member societies, which it is ready to serve in the ways directed, until it shall be succeeded by the new organization proposed by the Joint Conference Committee. Although complete changes will probably be made in personnel, Council aims to turn over to its successor, whenever the time comes, useful machinery in good order and active operation, so that there may be no hiatus in the "welfare" work of the Engineering Profession.

CLASSIFICATION AND COMPENSATION OF ENGINEERS*

The Just Basis for Fixing the Compensation of Engineers

In order to determine what is a fair rate of compensation for engineering service at the present time, the question may be approached from two different points of view: First, what increase should be made in engineers' pay to compensate for the great reduction in the value of the dollar which has taken place in the last five years? Second, how may the intrinsic value of engineering service be determined?

The Decrease in Value of the Dollar

A great deal of misunderstanding and injustice would be avoided in all our industrial relations were there a clear understanding of the fact that all prices today, whether of wages or salaries, or commodities, must be compared with the change which has taken place in the value of the dollar before it can be determined whether the price, measured by an absolute standard, has moved up or down. It should be obvious to everyone that the value of the dollar is measured solely by its purchasing power. Whether it be a dollar received as wages by workmen, a dollar received as salary by an engineer, or a dollar received by a manufacturer in payment for goods sold, the actual amount of value which will be received in each case *will depend upon the average amount of other commodities which the dollar received will purchase.*

Changes in "Cost of Living" and in "Value of the Dollar" are Not the Same

The customary reference to the general increase of prices above reviewed as "the high cost of living" has tended to confuse the minds of many people. Some employers have argued that the high cost of living was not their affair. They have declared the real trouble to be "the cost of high living." On the other hand engineers or other professional workers, and many classes of salaried men have hesitated to press claims for increased pay on the ground that changes in the cost of living make it difficult to live on their incomes. Such men rightly feel that their living expenses are their own private affair.

When, however, it is clearly understood that what has taken place is a change in the value of the dollar, the claim for an increase in the rate of pay measured in dollars rests on entirely different ground. The proper and dignified position for the engineer is to assume that his work should receive at least the same compensation in absolute value that it received five years ago and that therefore the compensation measured in dollars should be increased by whatever amount is necessary to offset the decreased value of the dollar.

There can be no denial of the justice of this claim, even though the difficulty of satisfying it to the full extent in many departments of engineering work is recognized. The compensation of many engineers is dependent upon laws and ordinances, custom and precedent. Great inertia must often be overcome to effect a change. In many cases the compensation of the engineer, like that of many other public servants, is dependent upon revenue raised by taxation; and the difficulties in increasing tax rates to correspond to the great decrease in the value of the dollar are known to everyone.

*Extracts from Appendix to Report of Committee, which report was published in the February JOURNAL.

Engineers engaged in business on their own account have to meet the difficulty of raising their fees to offset the changed value of the dollar, a task especially difficult in fields of engineering where work is inactive and the competition for it is keen; yet without such increase they cannot adequately raise the pay of their own employees. This illustrates anew the need for emphasizing the change in value of the dollar, rather than the change in living costs. The former is at once recognized to bear directly on fair prices for goods sold and for the fees charged by professional men as well as on wages and salaries.

On the other hand there are many cases where there is no real obstacle to a prompt adjustment of the engineer's compensation to the full amount indicated by the decreased buying power of the dollar. In carrying on construction work, the salaries paid to engineers are a small percentage of the total cost. The wage workers, both those organized in trade unions and even the unskilled and ignorant laborers on the work, have received increases in compensation in many cases fully equal to the change in the value of the dollar and in some cases far exceeding it. If the engineers on such work are paid the same percentage of the total cost that they were in 1914, their increased pay will fully offset the changed value of the dollar. The same thing is true of engineers employed in manufacturing industries, and here the compensation of engineers has been largely increased.

Justice to the Salaried Men

At this time especially, employers who represent invested capital and those responsible for work in the public service, stand in great need of the loyal support and cooperation of their salaried professional staff. It is exceptional where salaries have been increased to fully correspond to their decreased purchasing power. The injustice in thus reducing the rate of compensation for loyal and efficient service paid to the very men on whose brains and fidelity the country is more dependent than on any other class is truly a fatal error.

How Long Will High Prices Stay

There has been reluctance to raise salaries to correspond to the changed value of the dollar because of the idea that prices were to drop back with the conclusion of the war. So far from this being the case, the records show that following the lull in business after the armistice prices have risen above even the war time scale and are now at the highest point ever reached. Business has largely readjusted itself to the changed conditions and the activity in some lines exceeds that registered during the war.

At the bottom of the changed price conditions is the surplus of demand over supply. The only two things which can restore prices to their former level are increased production or decreased consumption. The outlook is that it will take years to again organize the world's equipment for production and distribution, including finance, transportation by land and sea, and merchandising, so that the demands of consumers may be met as before the war and prices be brought back to former level.

If this analysis be correct, then all classes of workers whose compensation is below the general level will continue to suffer a hardship. The inevitable tendency will be to drive the competent men in these poorly paid callings out into other better paid occupations. Delay in adjusting the pay of the engineer to compensate for the decreased value of the dollar, therefore, does serious harm not only to him but to the public.

It may well be argued further that the high scale of prices or low dollar value has continued now for fully three years. During that time the engineer who has had but little increase in salary has suffered a heavy monetary loss through causes entirely beyond his control. The present price level is not considered merely temporary by such of our Government agencies as the Department of Labor and the Federal Reserve Board or by such

economists as Irving Fisher* and J. S. Holden†. Substantial relief from the high cost of living therefore cannot reasonably be expected through a decrease in prices; it must be met by increases in salaries.

From the above considerations, the Committee feels justified in urging that a readjustment of compensation should be based on the assumption that the present scale of prices is to continue for an indefinite time.

The Intrinsic Value of Engineering Service

It will be generally agreed that the salary of an engineer ought to be at least sufficient to enable him to live in the manner which his position and responsibility call for, and in addition to repay within a reasonable time the investment in time and money he has made in gaining the education and experience which is necessary for his work.

The Living Wage Principle

There is a wide general acceptance of the principle that the worker in any occupation should receive at least a reasonable living wage. By a "living wage" is meant the amount which will maintain in decency and comfort both the incumbent of the position and his dependents.

There are certain positions which are ordinarily occupied by young men and women who are starting on their life work and who have not yet assumed family responsibilities. In so far as the incumbents of these positions fill them temporarily as a means of advancement to positions of greater compensation —in effect serving as apprentices—the living wage need not be based on a "family" standard. When, however, any position is likely to be occupied more than temporarily by individuals of an age at which they should naturally assume family responsibilities, the minimum salary for the position should not be less than that necessary to maintain an average family in respectability.

Why Engineering Work has Been Inadequately Paid

Unfortunately there has been for fully a decade a tendency to lower the pay of engineers. The law of supply and demand has operated to reduce the pay of engineers in many branches of the profession far below the standards above defined.

This has not benefited the public. On the contrary by paying too low a rate for engineering service, the inevitable tendency has been to lower its quality. This has been especially marked in the case of engineers in Federal, State and Municipal service. Here the inertia which prevails in all public affairs has prevented the engineers from receiving more than a trifling part of the increase in pay, measured in dollars, that is required to offset the shrinkage in the dollar value.

The obvious result has been to drive out of the public service the best and ablest men, who can obtain better positions elsewhere, and to leave only the men who by reason of age or inferior ability cannot make such a change.

Cheapened Engineering Service Means Waste and Danger

It cannot be too strongly emphasized that the public loses through cheap engineering service many times the amount it may seem to save through lower salaries. The professional engineer in a responsible position in designing, constructing or executive direction of important work should have initiative, sound judgment, broad knowledge and executive ability. Lack of these qualities often results in great loss of money, often by needlessly increasing the cost of work of which the public never knows. Safety of life and limb is also so frequently dependent on the skill and fidelity of the engineer that danger is incurred when the quality of engineering service is sacrificed through a false idea of economy. The investigation of the Quebec bridge disaster of 1907 showed that the engineer primarily responsible for the safety of its design was being paid at so niggardly a rate as to be unable to provide a sufficient and competent staff to properly supervise the work.

*Fisher, Irving. The New Price Revolution, U. S. Dept. Labor, 1919.
†Holden, J. S. Prices During the War and Readjustment period, U. S. Dept. of Labor, April, 1919.

The movement, therefore, to give engineers just compensation for their services is not merely a movement for the benefit of the engineering profession. It is even more a movement to benefit the public by securing for it a high quality of engineering service.

This matter deserves emphasis here because where readjustment of salaries has taken place to compensate for the changed value of the dollar it has been common to confine the increase to the lower paid men and to do little or nothing for the men receiving salaries above $2500 to $3000. There is no longer an excuse for this, as the above review amply proves. The measure of seeming economy, also, is very small; because the engineers in the higher poistions are few in number compared with the rank and file of professional workers.

Routine Workers in the Profession

It is frankly recognized that there is another class of technical work of a routine order which calls for little in the way of initiative, originality or judgment. Much of this routine technical work in the field, the office, the shop, or the laboratory can be and is being done by boys and young men with limited education and no more training than that afforded by a correspondence school or a few months study in a trade school. Most of this work does require, however, a degree of reliability and fidelity which deserves fair compensation. The best guide to fair rates of pay for this class of technical workers is found by comparison with the standard rates of wages paid to skilled workers in the trades. These workmen are now generally receiving rates of pay much higher than the routine technical worker and in many cases higher than even the engineer who carries large responsibility for design or administration.

The Federal Government is now paying thousands of its highly trained clerical and technical force less than a living wage. Except for the temporary bonus of $240 a year for positions paying salaries of $2500 or less, no attention has been paid to the constantly diminishing purchasing power of the salaries paid to this class of employees. On the other hand the Government has given full recognition to increased living costs in fixing the wages of organized labor.

A "shipfitter" in the Navy Yard, for example, receives $1750 a year while he is learning how to do his work. After three months of apprenticeship he gets $2000. If he is made a "straw boss" in charge of 12 or more men, he gets $2450, and if a "sub-foreman" in charge of 30 or more men, he gets $2900. A blacksmith (heavy fire) gets $2400. A "hammer and machine forger" (heavy) gets $3700.

In many instances the amount paid for skilled labor is greater than the amount paid to the trained Government engineer. Over 40 of the labor crafts were awarded a rate of wage of $2000 and more by the Labor Adjustment Board.

The skilled laborer is not required to know how to read or write, and he may receive full pay after an experience varying from two weeks to six months. The Government engineering employee, on the other hand, to get an equivalent amount of pay, must have had from two to eight years' experience if he is not a technical graduate, and in many instances will not be admitted at all without a technical degree and then only with from two to four years' practical experience.

Many other comparisons might be made between the worker at a trade or the factory employee and the routine worker in engineering, showing how low is the pay of the latter compared with the former; but no further proof is necessary to show that the technical worker is not receiving what his services are worth.

The inevitable result of such underpaid service is a deterioration in its quality. The men in these lower grades have as a rule not the same incentive of professional pride that often keeps the men carrying large responsibilities faithfully at work, even when their pay is inadequate.

Even though a temporary oversupply of men trained in engineering work may make it possible to keep salaries for these brain workers below the wages of laborers, the inevitable result

will be a dissatisfied working force, which carries out the daily routine without energy or good will, and the public's work will not be done with efficiency or economy.

Major Committee
Arthur S. Tuttle, Chairman,
Francis Lee Stuart
John C. Hoyt
Charles Whiting Baker
M. O. Leighton

Railroad Section
Francis Lee Stuart, Chairman,
Frank H. Clark
Bion J. Arnold

State and Municipal Section
Arthur S. Tuttle, Chairman.
M. M. O'Shaughnessy
F. W. Cappelen

Federal Section
John C. Hoyt, Chairman,
John S. Conway
Oscar C. Merrill

AMERICAN ENGINEERING STANDARDS COMMITTEE

After almost three years of investigation by the engineering fraternity, under the guidance of Professor Comfort A. Adams as Chairman, the revised constitution of the American Engineering Standards Committee, along with by-laws and rules of procedure, has been adopted, and has been ratified by the A. S. C. E., the A .I. M. &. M. E., the A. S. M. E., the A. I. E. E. and the A. S. T. M., and the three Government Departments, of Commerce, Navy and War. Each of these interests have three representatives, and although the Committee as it exists today consists of twenty-four members, the new Committee is of very wide scope and allows the direct or indirect participation of anyone interested in standardization.

Mr. A. A. Stevenson, the newly elected Chairman, is a Past-President of the American Society for Testing Materials, and Dr. P. G. Agnew, formerly of the U. S. Bureau of Standards, is now Secretary with headquarters at the Engineering Societies Building, 29 West Thirty-ninth Street, New York City.

The American Engineering Standards Committee makes it possible to give an international status to approved American engineering standards and to cooperate with similar organizations in other countries. Similar organizations are now functioning in Great Britain, France, Switzerland, Holland and Canada.

The American Engineering Standards Committee has already approved specifications for standard pipe threads, and are representing America on this subject at an international conference in Paris. Cooperation is in progress with the National Screw Thread Commission, looking forward to standard screw threads. The Committee is also in active cooperation with the Canadians on bridge specifications, with the British on machine tools and with the Swiss on ball bearings.

A conference of practically all national organizations interested in industrial safety has unanimously voted that all industrial safety codes should be prepared under the auspices of the American Engineering Standards Committee.

Any organization may request the Committee to approve standards which it has formulated, or to approve committees that it has appointed, and by so doing becomes a sponsor society. Two or more organizations may act as joint sponsors. Approval of a standard is given when it is the substantially unanimous conclusion of a section committee made up of representatives of producers, consumers and general interests, and so selected that all interests concerned have adequate representation on the section committee.

In addition to the work of assistant in the selection of committees and certifying that their work has been done under proper conditions, the Committee will act as a bureau of information regarding standardization.

CURRENT ENGINEERING TOPICS

POWER BILL STATUS

As this issue goes to press, it appears probable that the Water Power Bill, which has passed both the House and Senate, will come up for active consideration before the conference committee within a few days. This is made possible because the conferees serving both on the Railroad Conference Committee and Power Conference Committee, were released when that Bill was agreed to and sent back for final passage. It is contemplated that at least a month will be required for the adjustments which will be made in conference.

The conferees on the part of the Senate are—Jones of Washington, Nelson of Minnesota, Bankhead of Alabama, Smoot of Utah, Fall of New Mexico, and Myers of Montana; on the part of the House—Esch of Wisconsin, Sinnott of Oregon, Haugen of Iowa, Sims of Tennessee, Taylor of Colorado and Lee of Georgia.

It is realized by engineers that this legislation does not give all that could be wished or hoped for in the way of a national power policy or in the way of administering that policy, but when it is realized that this legislation has come through a long and tedious course, with very active opposition at every turn, it should be taken at its face value as at least a good beginning and as an opening upon which further improvement can very logically be based in the light of experience that will be obtained from the initial operations under this bill.

CONSERVATION THROUGH ENGINEERING

Past-Secretary of the Interior, Mr. Franklin K. Lane, has given considerable attention to the engineering features of the work of his department as is evidenced by the frequency and comprehensive references made to engineering work in the last annual report of the Secretary of the Interior, and especially to the printed extracts of that report which have been gotten out under a separate cover, for the purpose of lending cooperation to engineers.

The recent coal strike and the attention given it by the Interior Department is covered in considerable detail with pertinent questions asked and answered as to the means of conserving coal and meeting future emergencies of this kind. Under the heading "White Coal and Black" the question of waterpower is treated briefly.

Petroleum from the standpoint of its production from oil-shale and its use as fuel and generating power is treated with a comprehensive summary. It will be recalled that Mr. Lane was especially active with broad plans for soldier settlement legislation,—it was he that first introduced soldier settlement plans. Other phases of the reclamation and development program are covered in an interesting manner.

"Conservation Through Engineering" is a public document known as Bulletin No. 705.

UTILIZING GOVERNMENT INVENTIONS

In order that the public, the industries and the Government Departments may get the full benefit of scientific inventions and patents of departmental employees, a bill has been introduced by the Senate Committee on Patents, proposing to give the Federal Trade Commission authority to arrange for the development of useful inventions, patents and patent rights in the broadest way. This procedure is to be under such regulations as the President shall prescribe. The cooperation of all scientific or other agencies of the Government is assured for the discharge of the duties of the Federal Trade Commission.

The Federal Trade Commission is authorized to collect fees and royalties for licensing the inventions, patents and patent rights in such amounts as the President directs and is to deposit these fees in the United States Treasury, except the necessary percentages to be reserved in a special fund to be used to remunerate the inventors for meritorious ideas. The appropriations of Governmental Departments are made available for the payment of fees charged by the Patent Office in connection with the granting of patents under this Act.

PATENT LEGISLATION

Legislation covering the administration of patent law, the status of the Patent Office and our international relations in patent work have been very active in Congress. The House has passed a bill ratifying a Patent Convention which will enable holders of patents in this country and South American countries to have their patents registered and cleared through a common office at Havana. The registration fee is very small,—only a fraction of what it used to cost to have these patents registered.

The Senate and House bills authorizing the Federal Trade Commission to accept and administer inventions, patents, and patent-rights have been reported to both houses. This is for the purpose of benefiting and encouraging the public in an effort to stimulate inventions and to encourage their industrial use. This bill provides for cooperation as between individuals, Government and other agencies, and with scientific agencies of the Government. The House patent bill providing for increase of force and salaries in the Patent Office has been rewritten and reported to the House calendar. It provides that the Commissioner of Patents shall receive $6,000 annually; First Assistant to Commissioner, $5,500; and the Assistant Commissioner of Patents $4,500, with five examiners in chief, $5,000 each. Other salaries are raised in proportion.

Bill proposing to establish a Court of Patent Appeals has been re-written by sub-comittee of House Patents Committee and will be introduced to the House calendar shortly. Bill proposing to make a separate establishment of the Patent Office is now under consideration by another sub-committee.

THE EDISON PIONEERS

The Edison Pioneers tendered a luncheon and reception to Mr. Thomas Alva Edison and his family at Orange, New Jersey on February 11th, 1920 on the 73rd anniversary of his birth. Many interesting and unique features added to the interest of the occasion and supplemented the Annual Addresses of the retiring President Mr. John W. Lieb, Past President Francis R. Upton and the well chosen remarks of Mrs. Edison who responded for Mr. Edison.

At the Annual Meeting of the Edison Pioneers which formed part of the ceremonies the following officers were elected for the ensuing year: President, Major William J. Hammer; Vice Presidents—Alfred W. Kiddle, Samuel Insull, Charles L. Edgar, Sydney B. Paine; Executive Committee—Francis R. Upton, John W. Lieb, Dr. Edward G. Acheson; Secretary—Robert T. Lozier; Treasurer—Frederick A. Scheffler; Historian— William. H. Meadowcroft.

SCOPE OF THE INSTITUTE

In the address of President Townley at the opening session of the Midwinter Convention of the Institute, which is printed in full elsewhere in this issue, attention is called to the desirability of the Institute confining its activities to matters within the scope of engineering or closely allied subjects.

This topic was also discussed at a meeting of the Board of Directors of the Institute held February 18, at which time the following resolutions were adopted for the purpose of reaffirming the well-established policy of the Institute.

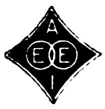
WHEREAS, many requests are received by the officers of the Institute and its Sections and Branches for support of candidates for political office and for various movements in activities outside of the field of engineering,

RESOLVED, that the attention of the membership be called to the undesirability of the Institute expressing views purporting to represent the collective will of the national, or any local, organization in matters outside of the scope of engineering and upon which the membership may hold conflicting opinions.

RESOLVED FURTHER, that attention be called to Section 61 of the By-laws, which reads as follows:

"SEC. 61. The principal work of a Section shall be the holding of regular meetings for the presentation and discussion of papers on matters relating to electricity, and to the allied arts and sciences. No action which may purport to represent the policy or organization of the Institute, or of any Section, shall be published or communicated to any party or parties who are not members of the Institute, without the approval of the Board of Directors."

NEW SIZE OF EMBLEM



This is a full size reproduction of a new membership badge, which has now been provided to meet numerous requests of Institute members for a smaller emblem. This badge which is half the size of the original is available in the vest pin, lapel button and scarf pin styles only, all patterns in solid 14k gold and finished in the same style as the larger membership badge. The lapel button is equipped with a screw back of plated gold. The price of the vest pin and lapel button styles is $3.00, and the scarf pin $3.50.

Members who desire to return their old membership badges for credit on the purchase of a new badge, will be allowed a refund of $1.00 for the return of a vest pin or watch charm, or $1.25 for the lapel button.

On account of limited space, the new badge will be provided without engraving.

INDUSTRIAL SAFETY CODES

On December 8th there was held at the Bureau of Standards in Washington a conference on industrial safety codes, at which there were representatives of practically all national organizations interested in industrial safety. The conference grew out of an earlier one held on January 15th, 1919.

After a thorough discussion the consensus of opinion was that there should be a large number of industrial safety codes developed during the next few years.

The subject is far-reaching. Vast financial and industrial interests are involved and the welfare of more than six million workers is directly involved, in the work of a single organization, the National Safety Council.

The conference unanimously voted that the preparation of all such safety codes should be under the auspices and rules of procedure of the American Engineering Standards Committee. In accordance with the recommendation of the conference, the American Engineering Standards Committee requested the International Association of Industrial Accidents Board and Commissions, the Bureau of Standards, and the National Safety Council to organize a Joint Committee on Safety Codes, this Committee to include representatives of these bodies, and such others as they may consider advisable, with the understanding:

(a) that this Joint Committee shall report upon safety codes required, priority of consideration of the codes, and sponsor bodies for their preparation.

(b) that the Joint Committee be requested to make a progress report by February 1st, 1920.

In compliance with this request of the Standards Committee, the three bodies have organized such committee.

The Committee held its first meeting in Washington on January 9th, at which time tentative recommendations were formulated for some thirty safety codes. It is expected that the Committee will be able to render an important preliminary report in the near future.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

REPORT FOR 1919

The annual report of the Library Board of the Engineering Societies Library for 1919 has been issued, from which the following items have been abstracted.

Contents. During 1919 the library received by gift 5707 books and pamphlets, and by purchase 785 books and pamphlets, making on December 31, 1919, a total permanent collection of 152,091 publications, all unaccessioned material having been examined during the year and either accessioned or placed among the duplicates.

Use. The number of readers using the library during 1919 showed a marked increase over 1918. The attendance during recent years has been:

1915	12,820
1916	13,848
1917	11,381
1918	15,063
1919	22,042

The low figure for 1917 is accounted for by the fact that it was necessary to close the library for a considerable period during that year.

In addition to the readers, the library has received many mail and telephone inquiries, over 2500 persons during the year having been helped by the library not represented in the attendance figures nor in the records of the Service Bureau, which has cared for work requiring extended research, the preparation of translations, and copies of articles and bibliographies. During the year 552 searches, chiefly bibliographic, were prepared in answer to specific inquiries. Some of these were of great extent, requiring the time of one or two people for weeks and even months. The number of translations made was 71, containing 227,300 words.

The value of the equipment for making photographic copies of articles has been more evident than ever before. The orders amounted to 2319 and required 23,951 prints. This is an increase of 101 per cent over 1918, showing that this form of assistance is widely appreciated. Copies have been made for engineers on every continent.

Technical Work. Arrangements for examining unaccessioned material, cataloging new accessories, and recataloging old material were made in May. Miss Margaret Mann, formerly Chief Cataloger of the Carnegie Library of Pittsburgh, was engaged as cataloger, and the department began work on July 1, since which time it has covered extensive ground. The total number of volumes cataloged or recataloged during the year was 8993; and aside from these much time was spent in collecting sets from their various locations, in correcting inaccurate records and in collating the sets of periodicals and government publications. An index to the new catalog, containing 2920 entries, was compiled, and 6899 cards were added to the catalog.

The general principles of classification and cataloging have been described in a report by Director Harrison W. Craver. He explains, in brief, that the new catalog will substitute for all the old catalogs an author catalog and a classed subject catalog, the latter to be accompanied by a very full index. The Brussels classification is the scheme most adapted to the library's needs—that is the Dewey classification as extended and modified by the Institut International de Bibliographe. This has more international acceptance than any other system and its principles and notations are quite generally understood. The fact that many users of the catalog will have some previous familiarity with its system will enable them to use it more readily and with less assistance; and the system is sufficiently comprehensive and elastic to meet successfully any demand that the library may have to place upon it.

Staff. Changes in the staff have been less frequent than in previous years, and the effect of experience in this library has been favorably shown in more helpful service to the readers. The readers have recognized the service rendered by the staff, and many have taken the trouble to express their appreciation of the help received.

Finance. The general library service has been carried out within the amount appropriated, and the Service Bureau has met its expenses from its earnings.

BOOK NOTICES (January 1-31, 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

APPLIED CALCULUS.

Principles and Applications. Essentials for Students and Engineers. By Robert Gibbes Thomas. 1919. N. Y., D. Van Nostrand Company. 490 pp., 45 exercises, 166 figures, 5 x 7 in., cloth, $3.00.

In this college text-book, the author has aimed to make clear the basic principles of the calculus and to show that fundamental ideas are involved in familiar problems. Effort has been directed toward the attainment of a working and fruitful knowledge of the elements of the subject and an ability to use it efficiently.

ATLAS AMERICA LATINA.

1919. General Drafting Company, Inc., New York. 196 pp., cloth, 11 x 16 in., $20.

The detailed maps which form the most important part of this atlas have been prepared from the best authorities. They

cover Mexico. Central and South America and the West Indies and are drawn to a uniform scale of fifty miles to the inch. Towns, railways, administrative divisions and physical features are clearly shown and a geographic index is provided.

The atlas also contains general maps showing steamship routes, ocean currents, natural vegetation, prevailing winds, summer and winter rainfall and temperatures, principal products, principal minerals and the language divisions of Latin America, as well as charts showing the foreign trade of each country and descriptive articles concerning their possibilities and conditions.

AVIATION. Theorico-Practical Text-book for Students.

By Benjamin M. Carmina, N. Y., The Macmillan Co. 1919. 172 pp., 92 diagrams, table, 8 x 5 in., cloth, $2.

The author discusses the theory of flight and the construction, rigging and maintenance of airplanes, and gives suggestions on flying. The treatment is non-mathematical throughout, but an appendix is included which gives the mathematical analysis of the laws governing flight.

DER BAU DES DIESELMOTORS.

By Kamillo Körner. Berlin, Julius Springer. 1918. 350 pp, 500 diagrams. 11 x 7 in. Cloth, 30 marks.

The present work is devoted to the practical details of Diesel engine construction and omits all discussion of theoretical considerations. The various elements of engines are discussed in detail and examples of the usual designs are given.

CHILTON TRACTOR INDEX. Vol. 3, No. 1. January, 1920.

Philadelphia, Chilton Company. 478 pp., 10 x 7 in., paper, $1.00.

The Tractor Index is a directory of the farm tractor industry of the country, which gives in tabulated form the specifications of the tractors on the market, lists of tractor and power farm machinery manufacturers, makers of parts and accessories and farm trucks. In addition to these directories, the volume includes a collection of data and articles on power farming, farm lighting plants, tractor testing, tractor standards and other topics of interest to users and dealers.

CONTROLLERS FOR ELECTRIC MOTORS.

A Treatise on the Modern Industrial Controller, together with Typical Applications to the Industries. By Henry Duvall James. N. Y., D. Van Nostrand Company. 1919. 354 pp. +43 pp., 259 illus. Cloth. 8 x 5 in. $3.

The aim of this volume, which is based on a series of articles published in the Electric Journal during 1917 and 1918, is to provide students, operating engineers and users of electrical apparatus, with a good general account of industrial controllers and an explanation of their principles of operation.

THE ELEMENTS OF ASTRONOMY FOR SURVEYORS.

By R. W. Chapman. 1919. Lond., Charles Griffin and Co., Ltd., Phila., J. B. Lippincott Company. 247 pp., 56 diagrams, 5 x 7 in., cloth, $1.75.

Although there are several excellent books on surveying that deal more or less thoroughly with astronomical observations, the author of this work believes that there is a need for an elementary work suitable for the student and for the surveyor who is taking up astronomical observation for the first time. The present work is an attempt to provide an elementary exposition, not only of the practical methods of observation and computation, but also of the main principles that must be thoroughly understood if the surveyor is to be master of his profession.

GOVERNORS AND THE GOVERNING OF PRIME MOVERS.

By W. Trinks. N. Y., D. Van Nostrand Co., 1919. 236 pp. + 28 pp., 140 illus., 6 × 9 in., cloth, $3.50.

This volume aims to present the principles and essentials of the subject in such a manner that the reader may be able to judge existing and future types of governors as well as the properties of prime movers with regard to regulation. It has been written to provide a text-book on the general subject of governors and governing, upon which, the author states, there is no book of any consequence in English. A selected bibliography is included.

THE GREAT LAKES RED BOOK.

A list of over 1000 Vessels of the Great Lakes, with the Name of Owner, Captain and Engineer of each Vessel.

Cleveland, The Marine Review, 1919. 159 pp., 5 x 3 in., paper, $1.00.

Gives a list of the fleets upon the Great Lakes as well as owners, captains and engineers. There is also a table showing capacity of ore-carriers and a port directory.

MINING MATHEMATICS SIMPLIFIED.

By James Wardlaw, Sr., Scottdale, Pa. 1919. 189 pp., 7 x 5 in., cloth, $2.50.

This volume gives simple arithmetical solutions for the problems which confront the practical miner. The author is engaged in preparing miners for examinations for certificates as fire bosses, foremen, etc., in the Pennsylvania bituminous coalfield and has written this text for their use.

THE NEW AMERICAN THRIFT.

The Annals of the American Academy of Political and Social Science. Vol. 87, No. 176, January 1920. Philadelphia, Pa. 248 pp., paper, $1.

CONTENTS: Introduction.—Thrift for the individual and the family.—Thrift for the nation.—American needs for capital; typical examples.—Thrift in resources and industry; typical examples.—The investment of savings.—The promotion and practise of thrift in different countries.—Suggestions for promoting thrift.

A symposium by a number of bankers, economists and business men on the desirability of thrift in national and individual life. The problem is broadly presented and discussed in its various phases by experts.

ORGANIZING FOR WORK.

By H. L. Gantt. 1919. N. Y., Harcourt, Brace & Howe. 113 pp. Cloth. 7 x 5 in. $1.25.

Our civilization depends, according to Mr. Gantt, upon the effectiveness with which our combined industrial and business system work, and recent revolutionary attempts to overthrow it are due to the failure of the present system to recognize fully its responsibility to the community. The author believes that there must be a return to the principle that the first aim of business is to render service to the community and that this result can be peacefully obtained by the use of familiar methods, whose use for the purpose he discusses in the present book.

THE PRINCIPLES OF ELECTRICAL ENGINEERING AND THEIR APPLICATION. Vol. 2. Application.

By Gisbert Kapp. N. Y., Longmans, Green & Co.; Lond., 6 x 9 in. Edward Arnold. 1919. 388 pp. Cloth. 173 diag. $6.

The present textbook is intended for all engineering students and also as a handbook for general engineers. For the latter, the author attempts to provide a work which will give him the fundamental principles of the subject and describe their application in practical engineering, without burdening him with minute details of design. It will, the author hopes, enable the general engineer to determine whether and how any particular piece of electrical plant can be used or adapted for a particular purpose.

Volume 1, dealing with Principles, appeared in 1916. The present volume treats of the applications of these principles in electrical machines.

PRINCIPLES OF METALLOGRAPHY.

By Robert S. Williams. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 158 pp. 75 illus., tables, 8 x 5 in., cloth, $2.

This is a brief introduction to the subject written for students of general science or engineering, who do not specialize in metallography but who will use it to a limited extent in connection with their professional work, and for general readers who wish an introduction to more specialized books. Particular attention is given to the applications of metallography.

RADIO ENGINEERING PRINCIPLES.

By Henri Lauer and Harry L. Brown. 1st edition. N. Y., McGraw-Hill Book Co., Inc., Lond., Hill Publishing Co., Ltd., 1920. 300 pp., 241 diag., 6 x 9 in., cloth, $3.50.

This is a general textbook on radio, written to present the extensive developments in the art made during the war. It consequently is largely devoted to the study of the characteristics and use of the three-electrode vacuum tube in radiotelegraphy and radiotelephony. Sufficient attention has, however, been given to the principles involved in older apparatus to meet the requirements of a general textbook.

THE RAILROAD PROBLEM.

The Annals of the American Academy of Political and Social Science. Vol. 86, No. 175. November, 1919. Philadelphia. Paper, 6 x 10 in., 252 pp., $1.

In this collection of articles by various economists, financiers and railroad men, emphasis has been placed on the current issues as to railroad regulation and the participation of labor in railroad management. The major topics discussed are government operation, current proposals for regulation, the unification of terminals and railway efficiency and labor.

SELENIUM CELLS and How They are Made.

Compiled and arranged by Samuel Wein. 1919. N. Y., The Progress Publishing Company. 33 pp., illus., paper, 8 x 6 in., $1.

This pamphlet presents a concise chronological review of the development of the selenium cell. The various types of selenium cells are described, briefly but explicitly, and diagrammatic illustrations of the more important ones are given. The descriptions have been prepared after an examination of the available literature.

SOUTHERN PINE MANUAL.

Standard Wood Construction. 1919. New Orleans, La., Southern Pine Association. 136 pp. + 10 pp., diagrams and tables, 4 x 6 in., cloth, $1.

This small volume is an engineering handbook for engineers, architects and builders. Tables are given showing the dimensions and properties of yellow pine beams and columns and joists, the specifications of various engineering societies, the permitted working stresses adopted by various cities, and miscellaneous tables of use to users of wood in construction.

THE STORY OF ELECTRICITY. Vol. I.

Edited by T. Commerford Martin and Stephen Leidy Coles. 1919. N. Y., The Story of Electricity Company. 661 pp., 11 x 8 in., cloth, $25. for vol. 1 and 2.

The authors of this volume have prepared an account in popular language of the development of the electrical industry, with particular reference to American achievement. After an introductory chapter on the beginnings of electrical science, the invention and growth of the telegraph, telephone, central station, electric railway, etc. are described. Chapters are devoted to the great electrical companies. The various chapters are accompanied by biographical sketches and portraits of engineers of prominence, past and present. Numerous well-selected illustrations add to the value of the work.

A TEXTBOOK OF RAND METALLURGICAL PRACTISE, Vol. 2.

By Ralph Stokes Jas. E. Thomas, G. O. Smart, W. R. Dowling, H. A. White, E. H. Johnson, W. A. Caldecott, A. McA. Johnston and C. O. Schmitt. 2nd edition, revised, 1919, Lond., Charles Griffin & Company, Ltd., 462 pp., 467 illus., cloth, 9 x 6 in., 25 shillings.

This work was prepared in 1911 by a body of technical men actively engaged in current metallurgical practise upon the Witwatersrand, to provide a textbook giving a detailed account of the methods in actual use in that district, both mechanical and chemical.

The present volume, which discusses the design and construction of reduction plants and the transport of materials is by C. O. Schmitt. No radical change in practise has occurred since the publication of the previous edition, but considerable progress in the development of the use of heavy stamps, and tube mills, and a corresponding advance in the methods of classification and amalgamation have been made. This revised edition has been prepared in the light of these improvements.

TEXT-BOOK ON WIRELESS TELEGRAPHY. Vols. 1 and 2.

Vol. 1. General Theory and Practise. Vol. 2. Valves and Valve Apparatus. By Rupert Stanley. New edition in 2 vols. 1919. Lond., N. Y., Longmans, Green & Company. Vol. 1, 470 pp.; Vol. 2, 357 pp. 6 x 9 in. Cloth, $10.

In the preparation of this textbook for the instruction of wireless operators, the author has kept in mind the special needs of those who have had little preliminary knowledge of electrical matters. He has therefore provided the instruction in elementary electricity and magnetism necessary for an understanding of the principles of energy radiation.

Calculations and formulas have been made as simple as possible in the technical portion of the book and the descriptions of apparatus have been restricted to the best modern types.

The present edition has been largely rewritten and rearranged. Much new matter has been included and a second volume, devoted to valves and valve apparatus, has been added.

OBITUARY

WALTER JAMES WARDER, JR., late Electrical Engineer with Roth Bros. & Co., Chicago, Ill., died on January 20, 1920. Mr. Warder, born Aug. 14, 1879, had his technical training in the Lewis Institute, Chicago, where he was a student for three years. His work in the engineering field lay in the design, manufacture, and application of electrical machinery. At first he was connected with the Western Electric Co. as electrical engineer, later with Roth Bros. & Co. as chief engineer, and a Director of the Company. He joined the A. I. E. E. as Associate in 1903, and became a Fellow in 1913.

NATHAN CORNING KINGSBURY, late Vice-President, American Telephone & Telegraph Co., New York, N. Y., died on January 24, 1920. Mr. Kingsbury was born at Mentor, Lake Co., Ohio, on July 29, 1866. His education, including a Classical Course at Oberlin College up to the Senior year, and a Legal Course at Ohio State University, was not technical, except as acquired by experience in the manufacturing business. After leaving college he was for several years in general business management with the Marinette Iron Works Co., Duluth, Minn., then for ten years Counsel for the Jeffrey Mfg. Co. of Columbus, Ohio. During the next two years he was Vice-President and President of the Michigan State Telephone Co., following which he became associated with the American Telephone & Telegraph Co. He has been an Associate of the A. I. E. E. since 1908.

ALBERT C. KNIGHT, of San Francisco, Cal., was seriously injured in a transmission tower accident on December 29, 1919, while in the employ of the Sierra and San Francisco Power Company. His injury resulted in his subsequent death on December 31, 1919. Mr. Knight was born in 1886 in Dayton, Washington. He finished a course in electrical engineering, after which from 1905 until the time of his death he had experience with several electrical companies of Washington, Oregon, and California.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Baltimore.—January 16, 1920, Engineers' Club. Subject: "Ship Propulsion." Speaker: Mr. W. E. Thau, Westinghouse Elec. & Mfg. Co. The lecture was illustrated by lantern slides and was followed by a lively discussion. Attendance 75.

Boston.—February 3, 1920, Boston City Club. The meeting was preceded by a dinner. Subject: "Large Turbo-Generator Units from the Operator's Standpoint." Speaker: Mr. Farley Osgood, Public Service Electric Co., Newark, N. J. The discussion was entered into by Messrs. Stahl, Mosher, Damon, Dillon, Rice and Sniffin. Attendance 275.

Cleveland.—January 20, 1920, Nela Park. In response to an invitation from National Lamp Works, members of the Cleveland Section, A. I. E. E., with other members of the Cleveland Engineering Society, gathered in the Cafeteria at Nela Park as their guests. A splendid luncheon was served, followed by talks bearing on Illumination by Messrs. Shenton, Roseburrow and Harrison. Practical demonstrations were given for calculating illumination and selecting the proper lighting units and reflectors for a given condition. Attendance 222.

February 17, 1920, Hotel Statler. Paper: "The Manufacfacture and use of Efficiency Instruments." Author: Mr. J. W. Esterline, President, Esterline Co. With the use of slides Mr. Esterline illustrated very clearly how a curve drawing instrument may be and is being used to find normal and abnormal conditions in production. He also illustrated many uses of graphic instruments of interest to the engineer responsible for the efficient operation of power consuming devices. Attendance 82.

Denver.—January 17, 1920, Shirley Hotel. The meeting was preceded by a dinner. Subject: "From Sugar Beet to Sugar." Speaker: Mr. D. J. Roach, who spoke on the history of the art, developments achieved in the chemical, mechanical and electrical features. The talk was illustrated by lantern slides and samples of the products of the process of sugar makking. A discussion followed which was participated in by two-thirds of those in attendance. Attendance 27.

Detroit-Ann Arbor.—February 20, 1920, Board of Commerce. Joint meeting of Detroit Ann Arbor Section, A. I. E. E., Detroit Engineering Society, and local Section of A. S. M. E., Paper: "Spectacular Illumination." Author: Mr. W. D'A. Ryan. Mr. Ryan's talk was very interesting and the paper was accompanied by interesting illustrations of specific installations. Attendance 300.

Fort Wayne.—January 15, 1920, G. E. Bldg. No. 16-2. Subject: "Johansson Gauging Tools." Speaker: Mr. Ernst Mentor, of the C. E. Johansson, Inc. Mr. Mentor's talk was illustrated with lantern slides and sample equipment. Attendance 145.

Indianapolis-Lafayette.—January 16, 1920, Chamber of Commerce, Indianapolis. Subject: "The Debt of the Automobile to Electricity." Speaker: Mr. Chester S. Ricker, who is widely known in the automobile world and represents the American Automobile Association in Indiana, Chairman of Technical Committee on timing and scoring at the Indianapolis Motor Speedway, author of text books and hand books, and is also a correspondent for American and English trade magazines. Attendance 28.

Ithaca.—January 16, 1920, Franklin Hall, Cornell University, Subject: "Some Electrical Temperature Devices." Speaker Dr. H. A. Clark, Physicist, Technical Department, Taylor Instrument Co. Dr. Clark in his lecture took up the principal thermal devices in which electricity is used, illustrating the fundamental principles by means of lantern slides. He brought with him and had in operation at the lecture, a small electric furnace with automatic temperature control, with a recorder for registering the temperature, and an indicator for showing at a distance whether the temperature is too low, right or too high; also a multiple recorder giving temperature curves from six thermocouples; a frost alarm and an electrically operated distance reading thermometer for use at room temperatures; a Fery total radiation pyrometer in use; an electrically operated automatic temperature control for an annealing oven. Attendance 135.

January 30, 1920, Sibley Dome, Cornell University. Subject: "Automatic Telephones" and "The Operation of Machine switching." Speaker: Mr. C. A. Berry, Central Office Engineer, American Tel. & Tel. Co. Mr. Bery's talk covered a description of the automatic telephone, its uses, its operation and some of the engineering problems involved. He brought with him some switching mechanisms and automatic telephones, which were seen in full operation at the lecture. The talk was illustrated with lantern slides. Attendance 275.

Lynn.—January 21, 1920, Lynn Classical H. S. Illustrated lecture on "The Manufacture of the Incandescent Lamp" by Mr. E. D. Stryker of the Engineering Department of the G. E Co., Nela Park, Cleveland. Attendance 200.

February 4, 1920, G. E. Hall. Subject: "Underground Cables, their Manufacture and Use Under Modern Practice." Speaker: Mr. R. W. Atkinson, Assistant Chief Electrical Engineer of the Standard Underground Cable Co. The lecture was illustrated by lantern slides. Refreshments were served. Attendance 110.

Madison.—January 28, 1920, Soils Bldg., Univ. of Wisconsin. Subject: "The Work of the Forest Products Laboratory." Speaker: Dr. C. P. Winslow, of The Forest Products Laboratory. The speaker gave a talk on the problems the Laboratory had to meet during the war and how they were met. This was followed by a moving picture which illustrated the actual work of the Laboratory. Attendance 18.

Philadelphia.—February 9, 1920, Engineers' Club. Subject: "Recent Developments in Electric Furnace Practice." Speaker: Prof. J. W. Richards, Lehigh University. Discussion by six representatives of manufacturing corporations marketing electric furnaces. Attendance 112.

Pittsburgh.—February 10, 1920, Chamber of Commerce Auditorium. Subject: "Industrial Electric Heating Applied to Medium and Low Temperature Processes." Speaker: Mr. W. S. Scott, Industrial Heating Section, Westinghouse Elec. & Mfg. Co. Attendance 27.

Portland.—January 13, 1920, Multnomah Hotel. Subject: Discussion of Einstein Theory, by Dr. William Conger Morgan, Professor of Chemistry at Reed College. After the meeting there was an informal dance and buffet luncheon. Attendance 125.

February 10, 1920, University Club. Paper: "The Electric Furnace for Brass Melting" by E. L. Kavanaugh, Electrical Engineer, Detroit Electric Furnace Company. The pap r was illustrated with lantern slides and two reels of motion pictures. Refreshments were served after adjournment. Attendance 75.

Rochester.—January 23, 1920. Subject: "Automobile Ignition Systems." Speaker: Mr. A. D. T. Libby, of the Splitdorf Company. Attendance 36.

St. Louis.—January 28, 1920, Union Electric Assembly Hall Subject: "The Technical Story of the Synchronous Con-

verter" Speaker: Mr. B. G. Lamme, Chief Engineer of the Westinghouse Electric & Manufacturing Co. Following the general lines of his paper Mr. Lamme gave some very interesting points in the technical story of the synchronous converter, showing the causes of different developments. Mr. H. W. Eales, Chief Electrical Engineer of the Union Electric Light and Power Company, then brought out the following additional ideas: (1) the d-c. voltage limits the a-c. voltage of synchronous converters; (2) users often specify unreasonable requirements; (3) the size of converters is limited by the area of the d-c. distribution; (4) small automatic substations may use more converters in d-c. distribution. Mr. Val A. Fynn made some remarks on developments in Europe on the same lines as encountered by Mr. Lamme. Talks were also given by Mr. J. L. Hamilton, Mr. A. H. Timmerman, Mr. Clarkson and Mr. Weichel. Mr. Lamme followed, clarifying points raised in the talks of others. Attendance 110.

San Francisco.—January 21, 1920, Engineers Club. Subject: "Electricity in Gold and Silver Mining Industry. Speaker: Mr. B. B. Beckett. Attendance 55.

Schenectady.—January 16, 1920, Edison Club Hall. Subject: "Commission Manager Form of Government. Speaker: Col. H. M. Waite, a former Manager of the City of Dayton. Col. Waite began his address with the discussion of conditions in American municipalities today, the general dissatisfaction which, he declared, was manifested toward the present form of municipal government. He also discussed the various forms of government as tried out in various municipalities in the United States, comparing the relative merits of each and arguing that the Commission Manager form had the most advantages and least disadvantages of them all. Attendance 275.

February 6, 1920, Edison Club Hall. The speaker of the evening was to be Mr. Calvert Townley, President of the Institute on "The Engineer, Employer and Employee," but Mr. Townley was delayed on account of a storm and arrived at the meeting too late to deliver his paper. He therefore gave a brief talk on the present activities in the Institute. While waiting for Mr. Townley's arrival informal talks were delivered as follows: Mr. W. B. Potter on the electric locomotive, covering some of his experiences with the installations now in operation; Mr. C. W. Stone outlined the reasons for the organization and the scope of the American Radio Corporation; Mr. L. T. Robinson discussed the modification of the Standardization Rules of the A. I. E. E. and gave some of the reasons for the changes which have been made; Mr. D. B. Rushmore on Hydroelectric developments. Attendance 90.

Seattle.—January 20, 1920, Arctic Club Assembly. Business meeting, followed by presentation of a paper on: "Electric Welding of Mild Steel With Particular Reference to Shipbuilding" by Professor William Spraragen. The paper described the recent developments in electric welding; the operation of resistance welding and arc welding. Prof. Spraragen explained the advantages of the various kinds of joints having various amounts of bevel on adjoining plates, different sizes of welding rod, etc. The discussion which followed was taken part in by Messrs. Harisberger, Terrell, Quinan, Bessessen, Rockwell, Des Camp, Jefferson and others. Attendance 70.

Toronto.—January 9, 1920, Engineers Club. Business meeting. Attendance 63.

January 30, 1920, Engineers Club. Business meeting, followed by a paper on: "Artificial Power-Transmission Lines" by Dr. A. E. Kennelly. Dr. Kennelly pointed out how little was actually known regarding what is taking place on the wires; therefore models of lines were made. By means of lantern slides Dr. Kennelly showed what he called thumb-nail formulas to take the place of the text book formulas which are pretty hard for the student to understand and interpret. Some interesting pictures were also shown of the artificial lines now in use. Attendance 71.

February 6, 1920, Engineers Club. Business meeting, followed by an interesting talk on "Polyphase Induction Motors" by N. C. Mills. The talk was illustrated by a number of lantern slides showing the various types of motors, coils, etc., and Mr. Mills explained in detail the advantages and disadvantages of the different types of end ring construction used for the rotors of squirrel cage motors, and also touched on the question of the right kind of babbitt for the bearings. Attendance 70.

Utah.—January 29, 1920, Commercial Club. Subject: "Principles of Automatic Operation." Speaker: Mr. Markham Cheever. Mr. Cheever spoke of relation of labor to operation in connection with automatic substations.

Washington.—February 10, 1920, Cosmos Club. Subject: "Electricity and Ship Propulsion." Speaker: Mr. Cheney of the Navy Department. Attendance 120.

PAST BRANCH MEETINGS

University of Arkansas.—January 20, 1920, Y. M. C. A. Hut. General Electric Company film entitled "The Benefactor" was shown. Attendance 46.

Bucknell University.—February 2, 1920, Electrical Laboratory. Demonstration and lecture by Professor Stettler on high tension voltage. Theory of the Tesla Coil. Attendance 55.

University of California.—December 3, 1919, Mechanics Bldg. Subject: "Electric Railways." Speaker: Mr. A. H. Babcock, Chief Electrical Engineer for the Southern Pacific.

January 28, 1920, Mechanics Bldg. Business meeting. Attendance 16.

California Institute of Technology.—January 26, 1920. Paper: "Design and Construction of a Small Electric Furnace" by Messrs. Woodbury and Bissirs. Attendance 18.

February 16, 1920. Papers: "Electricity in the Oil Industry" by G. L. Cory, and "Coal Mining and Electricity" by Prof. G. Forster. Attendance 30.

Clemson Agricultural College.—January 20, 1920, Physics Lecture Room. Subject: "Radio Telegraphy." Speakers: Professors W. E. Speas and W. H. Godfrey. Attendance 61.

February 3, 1920. Subject: "Relays as Applied to Industrial Motors." Discussions by: Messrs. Voight, Ford and Day. "Life of Pupin" by G. F. Ricker; "Current Events" by R. C. Sarratt. Attendance 46.

February 17, 1920. Subject: "Railway Locomotive" by Prof. S. B. Earle. Discussion by L. H. Lachicotte. "Current Events" by J. H. Schroder. Attendance 64.

Lehigh University.—February 12, 1920. Subjects: "Electric Welding" written by D. C. McGalliard, '19, delivered by Homer I. Moll, '19,—"Electrical Engineering in the Steel Mill" by Mr. David M. Petty, Chief Electrical Engineer, Bethlehem Steel Company. Social hour after the business meeting. Attendance 89.

University of Maine.—February 18, 1920, Lord Hall. A paper was read by Mr. Douglass on the "Electrification of Railroads," illustrated by lantern slides. Also short talks were given by Mr. Bisbee on the Harvard Radio School as it was during the war while he was there, and by President Jones on some of the electrical work in a shipyard where he had worked. Attendance 28.

Massachusetts Institute of Technology.—February 5, 1920. Papers: "Sales Engineering" by L. S. Simons, of the Reliance Elec. & Eng. Co.; "French Radio Sets" by D. S. Dellenbaugh, of Elec. Eng. Staff, M. I. T.; "Lighting Systems of Holmesville, N. Y." by D. B. McGuire, '21. Attendance 40.

University of Michigan.—January 21, 1920, Michigan Union. Smoker. Short talks by Professors Parker and Bailey and other members of the faculty. Music. Refreshments. Attendance 105.

School of Engineering of Milwaukee.—December 23, 1919. Subject: "Modern Systems of Transmission and Distribution of Electrical Energy." Speaker: Mr. G. C. Post, Chief Engineer of The Milwaukee Electric Railway & Light Company. Attendance 90.

University of Minnesota.—February 17, 1920, Engineering Building. Dr. G. D. Shepardson, of the Electrical Engineering Department, spoke on some of the early methods of signaling, as well as some of the later developments in radio and telephony. Mr. S. P. Shakleton, of the Development and Research Department of the American Tel. & Tel. Co., gave an interesting illustrated lecture on the work of his company, touching particularly those phases which have to do with long distance telephone lines. Attendance 27.

University of Missouri.—January 19, 1920, Engineering Building. Subjects: "Main Line Electrification" by L. H. Albus; "Economics of Main Electrification" by C. E. Koester. Attendance 20.

February 16, 1920, Engineering Building. Subject: "Electric Welding" by E. W. Kerr. Attendance 57.

Montana State College.—January 21, 1920, Assembly Hall. Moving picture show "Electrification of Milwaukee Railroad." Attendance 67.

University of Nebraska.—February 4, 1920, Physics Building. Mr. John C. Hoge gave an illustrated lecture on the water power possibilities of Nebraska streams, showing several pictures of present developments and of sites that could be developed.

North Carolina State College.—January 15, 1920, Classroom. Business meeting. Attendance 15.

January 19, 1920, Classroom. Business meeting. Attendance 25.

January 22, 1920, Classroom. Business meeting. Attendance 20.

January 30, 1920, Classroom. Subjects: "Progress in the Art of Communication" by G. W. Tiencken; "The New Sunlight Arc" by J. D. Wallace. Attendance 19.

February 3, 1920, Classroom. Business meeting. Attendance 15.

University of North Carolina.—January 19, 1920. Subject: "Wage Payment Systems." Speaker: Professor J. H. Mustard. Attendance 42.

University of Notre Dame.—Inspection tours as follows: January 8, Gary, Ind., Gary Steel Mills; January 9, Chicago, Ill., Power Plants of the Commonwealth Edison Co., and Western Electric Company; January 10, North Western Power Plant and Franklin Avenue Substation. Attendance 19.

January 19, 1920, Engineering Hall. Subject: "Storage Batteries in Trucks." Speaker: R. Hearn. Attendance 25.

Ohio Northern University.—January 28, 1920, Dukes Memorial. Subjects: "The Essex Power Station of the Public Service Co. of New Jersey, by H. D. Rank; "Commercial Motor Testing" by A. M. Rawand. Attendance 35.

Ohio State University.—February 11, 1920, Robinson Laboratory. Business meeting. Attendance 59.

Stanford University.—January 22, 1920, Little Theater, Stanford Univ. General Electric Company's film "The King of the Rails" was shown to a joint meeting of the Branch and the Mechanical Engineering Society. Mr. William Thomson, G. E. Co., spoke on the electrification of the mountain division of the Chicago, Milwaukee and St. Paul Railroad. Attendance 220.

January 29, 1920, Little Theater. Illustrated lecture on "A Vision of the Engineering Development of the West" by Mr. Robert Sibley. Attendance 150.

February 2, 1920, Mech. Engg. Bldg. Subject: "Hydroelectric Power Development." Short talks by different members. Attendance 23.

A. & M. College of Texas.—January 26, 1920, E. E. Bldg. Subjects: "The Generator" by D. V. Thomas; "Electrical Application" by R. D. Blumberg; "Statistics on the Electric Locomotive" by J. C. Horger. Attendance 28.

University of Texas.—January 26, 1920. A paper on "Wireless Communication" was read by the committee in charge of the program; "Development in Wireless Communication by W. L. Cox; "Wireless in the Navy" by J. P. Buchanan; "Wireless Sets as Navigating Instruments" by Clyde Young. Attendance 25.

Virginia Polytechnic Institute.—January 12, 1920. Mr. B. J. Beitman gave an interesting talk on "The Balancing of Rotors." Attendance 19.

University of Virginia.—February 4, 1920. Mechanical Laboratory. Lecture by Dr. Edgar, Dept. of Chemistry, on personal experiences of the application of science in the war. Attendance 27.

Washington University.—February 10, 1920. Paper: "Standardization" by Mr. A. L. Timmerman, Vice-President of the Wagner Electric Mfg. Co., of St. Louis, which outlined the progress in standardizing production, processes, material, etc., which has come about in large motor manufacturing plants in the last few years. Attendance 61.

University of Washington.—January 13, 1920, Forestry Hall. Subject: "Applications of Electric Welding." Speaker: Prof. William Spraragen. Attendance 15.

February 3, 1920, Forestry Hall. Subject: "Proposed New 15,000 Volt 3-Phase Transmission Line for the City of Seattle." Speaker: Mr. Glen Smith. Attendance 31.

Yale University.—January 27, 1920, Elec. Engg. Laboratory. Subject: "Present Problems in Electric Railways and Freight Haulage." Speaker: Mr. A. B. Cole, Asst. Mgr., Publicity Dept., Westinghouse Company, Pittsburgh, Pa.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities, is given below, together with the addresses as they now appear in the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Leonard W. Egan, Elec. Furnace Co., Alliance, Ohio.
2.—John McF. Fisher, Arapoho, Oklahoma.
3. G. Foung, Wedgeway Bldg., Schenectady, N. Y.
4.—J. P. Gailunas, 100½ Van Couver Ave., Detroit, Mich.
5.—Albert Kalin, City Light Dept., Seattle, Washington.
6.—Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.
7.—George L. Sewell, Porter Bros., Norfolk, Va.
8.—Bertrand Smith, Kellogg Hotel, Kellogg, Idaho.
9.—Wm. A. Street, Gatun, C. Z.
10.—Lieut. W. J. Strieby, 34 Simpson Road, Ardmore, Pa.
11.—Lieut. T. W. Swartz, 53, D. Infantry, Chattanooga, Tenn.
12.—A. S. Touche, 72 West Adams Street, Chicago, Ill.
13.—R. M. Umberger, 504 West King Street, Lancaster, Pa.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

YOUNG ELECTRICAL ENGINEERS for power sales engineering work. Must be able to make own tests and reports, and lighting motor and equipment layouts. Work also includes application of gas to industrial processes, and the supplying of high and low pressure to some sections of the city. Salary $115 per month. Location New York State. Z-237.

ELECTRICAL ENGINEER technical graduate, about 25 years of age, to have charge of all electrical equipment and part of the mechanical equipment of an industrial plant. Location New York City. Z-238.

ELECTRICAL DRAFTSMEN familiar with switchboard and control diagrams; also man for substation and general wiring layouts wanted by large industrial concern in middle west. Reply should state education, qualifications, experience and salary expected and preferably give references. Z-246.

YOUNG ILLUMINATING ENGINEER capable of designing show window and commercial lighting installations; selling experience desirable but by no means essential since the man selected to do designing will be assisted by competent commercial lighting salesmen. Location Tennessee. Z-260.

MAINTENANCE ENGINEERS for A-C. and D-C. motors. Location New York City. Z-261.

ELECTRICAL DESIGNING DRAFTSMAN, preferably one who has had experience in power plant designing. Some experience in transmission line designing desired. Salary $175 per month with the assurance of an increase should the man prove fit for work. Location Washington, D. C. Z-272.

PLANT OR WORKS ENGINEER—Mechanical Engineer with experience as works Engineer or Assistant to Works or Chief Engineer; to assume supervision of mechanics, draftsmen, electricians and general plant maintenance and construction, also generation and distribution of power, etc. Position is with large concern where prospects are good. Experience with chemical or textile plants desirable although not essential. State experience in full, salary desired and when available. Location Cleveland, Ohio. Z-287.

ELECTRICAL DRAFTSMEN familiar with industrial plant design embracing electric light power layouts, underground distribution systems, transformers and rotary convertors substations, and telephone and signal systems. Location New York City. Z-293.

TELEPHONE ENGINEER with some operating experience and experience in the valuation of telephone properties. Salary $3600 per annum. Location Illinois. Z-295.

ELECTRICAL DRAFTSMEN for telephone switchboard drafting department. Telephone experience not necessary. Salary to start per week $24-34. Location Chicago, Ill. Z-303.

TELEPHONE ENGINEERS; men with considerable electrical training, preferably in telephone work. Salary to start per week $26-42. Location Chicago, Ill. Z-305.

MANUFACTURING INVESTIGATORS; should have some technical training and considerable shop experience; must be able to make time studies and plan operations. Salary to start per week $34-40. Location Chicago, Ill. Z-306.

MALE EMPLOYMENT MAN to interview candidates and hire them for shop work. Must have had shop experience and be able to handle men. Location Connecticut. Z-316.

MACHINERY PURCHASING AGENT for a large manufacturing company in the East. Technical graduate not over thirty-five years of age with knowledge of sources of supply and construction of both small and heavy machinery and tools of all descriptions. Knowledge of rubber machinery preferred but not essential. Give references, and salary expected to start. Z-318.

ELECTRICAL LABORATORY INSTRUCTOR at Throop College of Technology beginning Fall term 1920-21. Address applications, Professor Electrical Engineering, Throop College of Technology. Pasadena, California. Z-319.

SEVERAL DRAFTSMEN, all grades, familiar with merchant and naval marine installations. College men with other experience considered. Location Pennsylvania. Z-322.

OPERATING ENGINEER to take charge of an eight-hour shift in a 30,000 kw. Central Station. Young technical man if possible, to handle the system of scientific control which it is hoped to install. Position will pay about $165 per month. The shifts are working 8 hours, and the men have one Sunday off every third week, so that the position really is a little better than the average operating job. Location Pennsylvania. Z-331.

CHIEF DRAFTSMAN who will be in charge of all draftsmen in the civil, mechanical and electrical departments of an industrial concern. Will need to have had broad experience in industrial plant engineering, and be able to assist and direct draftsmen on layouts of mechanical and electrical equipment consisting principally of conveying machinery, milling and mixing equipment layouts, high pressure hydraulic equipment consisting of high pressure pumps, extruders, accumulators, and the pipe lines connecting same, high pressure and low pressure steam lines and equipment, power plant equipment, power generating plants, and general building design work. Location Cleveland, Ohio. Z-335.

COLLEGE GRADUATE IN ELECTRICAL ENGINEERING who has had considerable experience in the practical or operating end of electrical work as applied to industrial plants. Duties will include making up reports, visiting factories to take care of electrical troubles, and revisions and installations of new equipment. Location, Cleveland, Ohio. Z-338.

ELECTRICAL ENGINEER with experience in design of D-C. generators and motors of medium and large size. Must be technical graduate, and have had about five years design experience. Permanent position with opportunity for advancement for qualified designer. In applying, state education and practical experience since graduation. Location Pennsylvania. Z-340.

EASTERN CONCERN opening up complete gear manufacturing department needs services of experienced estimator or engineer familiar with spur, worm and herringbone gear business, and capable of taking care of estimates and correspondence. Location Maryland. Z-341.

SERVICES OF TWO YOUNG ELECTRICAL ENGINEERS wanted; recent technical graduate preferred, for A-C. industrial control design. Splendid opportunity. Write stating education, age, nationality, salary and when available. Location Newark, N. J. Z-342.

MECHANICAL ENGINEER: Well established builder of A-C. and D-C. generators and motors, desire high class man experienced in mechanical design of electrical machinery. Immediate opening. Location Ohio. Z-371.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING with practical experience in telephone engineering, to have charge of courses in telephony and be able to teach some courses in general electrical engineering. Position open September 1, 1920. Salary about $2700 first year. Location-State College in Middle West. Z-381.

RECENT GRADUATE from some reputable technical school, whose training has been in mechanical or electrical engineering and who would fit into power plant work, covering tests, analysis, design and construction. Location Conn. Z-382.

INDUSTRIAL ENGINEERS; technically trained men to become efficiency and cost experts for wood-working association. Employment by year with expenses paid. Traveling most in Central Western section. Address Thomas D. Perry, Grand Rapids, Mich. Z-385.

CONSTRUCTION ENGINEER preferably of college or technical training with experience in handling of material coming into the construction of power houses and sub-stations along mechanical lines from driving the piling to completing the stacks. Should be conversant with design so as to be able at least to make initial computations to check designs against constructional experience. Organization is such, that man is not only brought closely in contact with design work but is given opportunity to familiarize himself with operating conditions. Location Rhode Island. Z-388.

POWER HOUSE SUPERINTENDENT with a first-class license and acquainted with up-to-date power plant practises, connected with production of steam, electricity and refrigeration. Technical graduate preferred. Location Mass. Z-391.

GRADUATE ELECTRICAL ENGINEER with gas or marine engine experience for electrical house lighting and plant development work. Man 25-30 years of age desired. Location New York City. Z-402.

EXECUTIVE SECRETARY—We have an attractive opening, probably to locate at our Cleveland office, for a technically educated man, preferably between 30 and 35 years old, who has had broad experience in manufacturing business using steel as raw material. Familiarity with cost accounting, sales, statistics and general administrative features of such business essential. Candidates must possess ability to meet and tactfully deal with business executives, and a ready command of written English. In reply state age, college or technical school from which graduated, date and degree, whether married or single, specific, chronological account of business experience, present and expected salary. Scovell, Wellington & Company, Certified Public Accountants and Industrial Engineers, New York, Boston, Springfield, Cleveland, Chicago. Address reply to 110 State St., Boston, Mass. Z-418.

ENGINEER experienced in time study for position in factory manufacturing all kinds of wire for electrical purposes. Location New York State. Z-433.

MECHANICAL AND ELECTRICAL ENGINEER familiar with design and construction of factory power plants, heating systems, and general lighting and power wiring for industrial plants. Work will consist of supervision of design and installation of mechanical and electrical features of industrial plant equipment. Location one of the largest cities of southeastern Canada. Z-442.

MECHANICAL OR ELECTRICAL ENGINEER with good knowledge of general power plant work for board work. Salary $45-50. Location New York City. Z-451.

MECHANICAL AND ELECTRICAL ENGINEER; should be technical graduate; will be required to handle office details in connection with power program. Will work in as assistant to construction engineer. Starting salary approximately $200-250 per month. Location Ohio. Z-457.

ELECTRICAL ENGINEER—college graduate. Should possess good personality, be tactful and able to supervise men. Should be experienced on substation and general power plant work. Starting salary approximately $275 per month. Location Ohio, Z-462.

ELECTRICAL ENGINEER experienced in electrical computations of all kinds, especially of wire and cables. Location New York State. Z-464.

ELECTRICAL ENGINEER; recent graduate for field and testing work. Location New York City. Z-468.

RECENT GRADUATES OF MECHANICAL OR ELECTRICAL ENGINEERING COURSES for engineering work connected with production of electrical and mechanical devices. Send application to Mr. J. C. Wilson, the Cutler Hammer Mfg. Co. Milwaukee. State training, experience in industrial plants, if any, references and other information concerning yourself. Z-476.

GROWING-PROGRESSIVE CORPORATION is prepared to develop, manufacture and market a few additional products, preferably small devices used in electric power plant construction. Will consider adding to its staff, engineer with such devices or ideas so as to assit in their development. Location Pennsylvania. Z-479.

ELECTRICAL DRAFTSMEN with experience along designing of electrical switching equipment, etc. for central stations. Location Wisconsin. Z-480.

DRAFTSMEN WANTED FOR PANAMA CANAL: 2 Electrical Draftsmen, one experienced in underground power distribution and building illumination and one power plant designer. Advise minimum salary will accept. 1 Marine Machinery Draftsman, $208 month. Applicants must be thoroughly experienced in special lines above indicated, American Citizens (final papers) under 50 years of age, in good health. Free steamship transportation from New York or New Orleans, salary beginning date of sailing. Write "Chief of Office, The Panama Canal, Washington, D. C." Z-485.

UNION COLLEGE invites correspondence regarding instructorship opening next school year in the Electrical Engineering Department. Location New York State. Z-495.

CHIEF ENGINEER for power station. Plant comprises 2-1500 kv-a. General Electric horizontal turbines, surface condensers, cooling pond, four Badenhausen boilers, stoker equipment. Type of man required is one who has had operating experience in central station work, capable of moulding and directing his own organization and keeping the plant in good operating condition. Man not over forty-five years of age preferred. Salary not less than $200 per month. Location Ohio. Z-523.

ASSISTANT CHIEF ENGINEER; graduate of good technical institution, who has had at least five years experience in Engineering Department of large manufacturing plant. Must have good executive ability. Location Penn. Z-526.

MANUFACTURING COST MEN. Men with sufficient knowledge of fundamentals of cost keeping to be able to originate cost keeping systems for manufacturing operations and to formulate reports which will bring necessary facts concerning operating and production, etc., to the attention of executives for their guidance, desired. Location Boston, Mass. Z-528.

ELECTRICAL ENGINEER one year out of college for general work in engineering department of large central station. Salary $125 per month. Location vicinity of New York City. Z-535.

SALES ENGINEER AND INSIDE MAN to handle secretarial work, for concern manufacturing outdoor substation equipment for electric power companies. Two openings. Salary about $200 per month. Location Pennsylvania. Z-537. A. & B.

UNIVERSITY OF WISCONSIN, Electrical Engineering Department, desires to appoint an Assistant or Associate Professor of Electrical Engineering qualified to assume charge of the Central Station and Electric Railway Courses. An experienced engineer who has carried on investigative work resulting in contributions to the art is desired. R-2080.

ELECTRICAL ENGINEER experienced in electrical construction and operation including high tension and substation work, switchboards, building wiring, underground installation, etc. Should have experience in cable splicing and be familiar with the installation of synchronous motors of 500 horse power and up, should have knowledge of control panels. Must be able to handle at least 100 men including inspectors. Starting salary approximately $250. per month. Location Ohio. Z-554.

EXCELLENT OPPORTUNITY is open for technically trained man to become associated with prominent engineering organization in capacity of sales engineer. Knowledge of general power plant engineering is essential. Salary will be commensurate with ability. Send photograph together with record of your work. Z-557.

INDUSTRIAL PHYSICISTS. An established research laboratory of well-known manufacturer offers positions to qualified scientific men who have research ability. One or two men of scientific training in physics and experience in research are desired. There is also position open for a physicist with less experience but with creative ability. Working conditions are attractive and positions are permanent. Location Ohio. Z-558.

ENGINEER with creative and analytical ability and pleasing personality is desired by a laboratory interested chiefly in the development of lighting. Some experience in lighting desirable though not essential. Permanent position amid pleasant surroundings awaits one who can qualify. Location Ohio. Z-559.

TECHNICAL GRADUATE in electrical engineering with one or two years practical experience, for position in Engineering Department of large electrical manufacturing concern. First class opportunities for advancement. Location Canada. Z-569.

SERVICES AVAILABLE

Assistant Professor of Electrical Engineering, in one of the strongest engineering schools in the east desires responsible position in industrial field requiring engineering sense and executive ability. Age 36; married; available July 1, 1920. Minimum salary $4000. E-2070.

Manager of Small Manufacturing Concern; graduate E. E. and C. E.; age 29; married; varied experience including 3½ years along lines of production, routing, scheduling, costs, control, etc. E-2071.

Associate Professor of Electrical Engineering at state university of recognized standing desires greater opportunity. Age 34. Thoroughly trained, B. A. and E. E. degrees; excellent practical and teaching experience. Wants more executive responsibility. E-2072.

Electrical Engineer; graduate E. E. 1916; age 27, single, at present in consulting engineering office. Four years' varied experience including two years' G. E. test. Have had accounting and business training. Desires position as electrical engineer or as assistant manager in power plant; prefers West. Best references. Salary $2500. Available on application. E-2073.

Manufacturers.—Expert production executive; age 28, married, available on short notice. Graduate engineer with varied experience in production, valuation and construction fields. Location immaterial. E-2074.

Electrical Executive; with broad practical engineering and manufacturing experience, and two years' teaching experience in charge of electrical engineering department of well known college, wants to re-enter industrial field. University graduate electrical engineer 1908, married, age 35. Possesses initiative, perseverance, common sense, and executive ability. Salary $4000. Available July 1st. E-2075.

Experienced Electrical Engineer, now finishing power station construction of about 100,000 kilowatts, desires responsible position with engineering firm or position of Electrical Engineer or Superintendent of power with public utility or manufacturing company. Fourteen years' experience design, construction and operation of power stations and distribution. Electrical engineer degree. Minimum salary $5000. E-2076.

Fellow of Institute; with fifteen years' consulting and lecturing experience; formerly on faculties of engineering of two leading Universities. Has special knowledge of electric furnaces, power plants and engineering quantities and estimates. Good negotiator of contracts. Would compile bulletins and catalogues, or write artistic advertisements. E-2077.

Executive; age 38, married, twelve years' experience in coast artillery and ordnance holding positions of responsibility involving technical knowledge and executive ability. Desires executive position in eastern United States with live company in manufacturing or business offering opportunity for expansion. Salary $6000. E-2078.

Commercial Manager; Engineer at present actively engaged in new business end for central station company. Capable of taking charge of new business department in city of forty to fifty thousand. Available thirty days' notice. E-2079.

Graduate Engineer; age 44, 22 years' continuous business experience, 14 years as head of own company. Qualified in construction, maintenance and operation of power plants and public utilities. Head of efficiency and industrial engineering unit of army bureau 1918. Five years on roadways, sewerage and drainage systems. Salary $6000. E-2080.

Position in Southern California. Minimum salary $6000. Electrical Engineer, Massachusetts Institute of Technology 1903. One year outside construction; fourteen years in testing, designing, publicity and commercial engineering departments, Westinghouse and General Electric; two years consulting capacity steel plant electrification. Present position excellent. Desire to move family to more equable climate sole reason for change. E-2081.

Technical Graduate with three years' practical experience in power plant and manufacturing, and four years' sales work. Special training as executive in sales work. Position desired where future is limited only by ability. Age 30; location in West. Salary $3600. E-2082.

Electrical Engineer with thirteen years' experience covering plans, estimates and specifications for generating stations, substations, industrial installations, overhead and underground distributing systems, street lighting installations, and general electrical engineering combined with commercial and executive experience, desires position. Age 36. Salary $5000. E-2083.

Representation in Central Europe; Professional engineer, University graduate; age 35; married, Associate Member A. S. C. E., A. S. M. E., A. I. E. E., A. W. W. A.; 15 years successful practise in America and Europe, invites correspondence with firms wishing a first class representative, residing in Prague, Bohemia. E-2084.

Electrical Engineer; with extensive mechanical experience and sales training. Has manufactured and sold storage batteries, automobile electrical equipment and commercial motors and generators. Last two years production manager on fractional h. p. motors. Understands mass production and scientific management methods. Age 42. American; married; excellent physical condition. Eastern location preferred. E-2085.

Electrical-Mechanical Engineer; Professor of railway and electrical engineering, consulting engineer, will be available from the middle of June to the middle of September as expert in design, supervision, test or investigation work in connection with railway, steam and electric power generation and transmission, lighting or industrial problems. E-2086.

Electrical Engineer; age 27, married, desires responsible position, Ontario preferred. 12 years' experience on manufacture installation and operation of power house and substation equipment. Thorough knowledge of all classes of equipment including steel mills and electric furnaces. Salary $2400. E-2087.

Electrical Engineer; 10 years' experience, construction and installation, substation and transmission, both overhead and underground, 10 years in supervisory capacity, minimum salary $3000. can furnish references as to character and ability. E-2088.

Electrical or Plant Engineer; over 10 years' practical experience in manufacturing and industrial plants on design and construction of general equipment. Technical education. Minimum salary $3000 per year. Location preferred, vicinity New York City. E-2089.

Technical Graduate; University of Michigan '16. Associate. 3½ years with large telephone company on outside plant engineering. Age 29 years; married. Good mechanic; familiar with design and cost of all types of pole line transmission. Desires connection with consulting firm, traction or power company. Available on 30 days' notice. E-2090.

Experienced Welding Engineer; electric arc and spot welding, also acetylene welding and cutting. Good executive and organizer, hull and sheet metal draftsman. Desires permanent position to take charge of welding department to produce maximum results. Formerly Assistant-Head Electric Welding, Emergency Fleet Corporation. Age 32, married, best references. E-2091.

Sales Engineer:—live wire; six years experience; technical graduate; age 28, will consider high grade proposition. Expert steam turbine, pump, air compressor, and boiler equipment man. Experience also on cranes, electric motors and generators. Both ship and selling experience. Available on reasonable notice. A-1 reference. E-2093.

Capable-Executive: technical graduate; manufacturing experience of electrical and mechanical nature, consisting of factory work, testing, inspection, supplemented by general and production engineering, desires to connect with manufacturing concern in the east, age 30, married, salary $4500. E-2094.

Head of Department of Electricity and Telephony at well-known correspondence school desires position as Associate Professor of Electrical Engineering. 4 years' experience in field; 6 years' of combined teaching, consulting engineering and executive educational work. Technical graduate, 1910; degree, M. E. Age 34, married. Available on six week's notice. Salary $3000. E-2095.

Electrical Engineering Graduate, completing G. E. test, wishes position in New York City. Preparation, character and recommendations of the best. Prefer work involving power; generation, distribution and application. E-2096.

Electrical Engineer; age 31; married; at present head of department of electrical engineering in college of engineering of recognized standing. Also six years practical engineering experience, including three years with General Electric Company in test and engineering departments. Desires position which affords good opportunity for advancement as engineering ability is proven. E-2092.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED FEBRUARY 18, 1920

*Abbott, Donald A., Commercial Sales Engineering Dept., General Electric Co., Ft. Wayne, Ind.
*Abreu, C. S., Member of Firm, A. Braga & Co., Rua do Rosario 13-A., Sao Paulo, Brazil, S. A.
*Anderton, Thomas R., Engg. Dept., Brown Cos. Paper Mills, Berlin, N. H.
*Appuhn, William E. F., Instructor in Mathematics, Stevens Inst. of Technology, Hoboken, N. J.; res., 550 State St., Brooklyn, N. Y.
Arnold, Ellis J., Senior Student in Elec. Engineering, University of Michigan; res., 707 Oxford Road, Ann Arbor, Mich.
*Aslanides, D. J., 7 Rue Keumourdji, Pera, Constantinople, Turkey.
*Bach, Roy O., Senior Electrical Engineering Student, Univ. of Washington; res., 4113, 7th Ave. South, Seattle, Wash.
*Baker, Douglas B., Salesman, International Western Electric Co., 195 Broadway, New York, N. Y.
Baker, George C., Asst. to Gen. Foreman of Electric Construction, Brooklyn Edison Co., Brooklyn; res., 1929 Washington Ave., New York, N. Y.
*Ballard, Harold L., Instructor in Elec. Engineering, Univ. of Michigan, 109 New Engineering Bldg., Ann Arbor, Mich.
Ballew, Walter W., Commercial Engineer, Westinghouse Elec. & Mfg. Co., 1333 Candler Bldg., Atlanta, Ga.
Beedenbender, Harry L., Electrical Laboratory Asst., Harbishaw Electric Cable Co., Yonkers, N. Y.
*Benjamin, Abraham S., Electrical Engineer, Morkrum Co.; res., 4841 N. Central Park Ave., Chicago, Ill.
*Billstein, Arthur E. F., Student, Univ. of Pennsylvania, Philadelphia; res., 24th & Crozer Sts., Chester, Pa.
*Birch, Leland W., Electrical Engineer, Phoenix Utility Co., Hartsville, S. C.
Blatchley, Henry, Manufacturing Engineer, Winchester Repeating Arms Co.; res., 12 Prospect Place, New Haven, Conn.
*Blunk, A. Dolf, Street Railway Engineer, Durham Traction Co., Durham, N. C.
Bond, Thomas D., Power Engineer, Charles H. Tenney & Co., 201 Devonshire St., Boston, Mass.
Brackett, William H., Electrical Engineer, Lockwood, Greene & Co. of Canada Ltd., 285 Beaver Hall Hill, Montreal, Que.
*Brinkman, Erwin E., Industrial Research Engineer, Operating Research Bureau, Public Service Bldg., Milwaukee, Wis.
*Brown, Henry Speight, Sub-Lieutenant; Radio Engineer, Dept. of Naval Service, Ottawa, Canada.
Brunson, Lawrence W., Instructor in Elec. Engineering, University of Michigan; res., 836 E. University Ave., Ann Arbor, Mich.
*Burger, Edward J., Proprietor, Universal Storage Battery Equipment Co., 736, 3rd Street, San Bernardino, Cal.
*Cappon, Marvin T., Electrical Draftsman, Shepard Electric Crane & Hoist Co., Montour Falls, N. Y.
*Church, Leroy, Cadet Engineer, Public Service Co. of N. J., Marion Power Station; res., 78 W. Front St., Redbank, N.J.
*Colburn, Wellen H., Sales Engineer, Thomson Electric Welding Co., Lynn; res., 114 Grand Ave., Wollaston, Mass.
*Cowgill, Lester B., Somers, Mont.
*Cox, Carl C., Asst. Engineer, Fort Worth Power & Light Co., Fort Worth, Texas.
*Dart, Harry F., Asst. Principal in Elec. Engineering, International Correspondence Schools; res., 924 Green Ridge St., Scranton, Pa.
Dominick, William G., Transformer Engg. Dept., General Electric Co.; res., 215 Elm St., Pittsfield, Mass.
*Eberhardt, Wallace W., Asst. Engineer, Alabama Power Co., 639 Brown-Marx Bldg., Birmingham, Ala.
*Ekdahl, Edwin A., Asst. Supt. & Engineer, Amos Bird Co., Shanghai, China.
*Eslick, Everett, Industrial Engineering, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 691 Center St., Wilkinsburg, Pa.
Fairman, James F., Instructor in Electrical Engineering, Univ. of Michigan; res., 120 N. Division St., Ann Arbor, Mich.
Fenstermacher, Charles N., Telephone Engineer, Western Electric Co., New York, N. Y.; res., 77 Maolis Ave., Bloomfield, N. J.
Fowler, Clarence B., Telephone Engineer, Western Electric Co.; res., 290 West 12th St., New York, N. Y.
Friis, H. Trap, Research Dept., Western Electric Co., 463 West St., New York, N. Y.
From, Owen C., Circuit Engineer, Western Electric Co.; res., 508 W. 112th St., New York, N. Y.
*Fronmuller, Theodor C., Asst. Electrical Engineer, Pacific Gas & Elec. Co., 445 Sutter St., San Francisco, Cal.
*Gadberry, Joseph L., Electrical Engineer, Dallas Power & Light Co., Interurban Bldg., Dallas, Texas.
Galsterer, Andrew, Substation Operator, United Railroads of San Francisco; res., 1102 Masonic Ave., San Francisco, Cal.
*Gefke, Jerome H., Transmission & Protection Engineer, Wisconsin Telephone Co.; res., 605 Van Buren St., Milwaukee, Wis.
*Gittings, William N., Switchboard Requisition Engineer, General Electric Co.; res., 707 South Ave., Schenectady, N.Y.
Glasser, Charles E., Industrial Control Engg. Dept., General Electric Co., Schenectady, N. Y.
*Goldammer, Charles J., Elkhart Lake, Wis.
Grafing, Fred H., Engineer, Electrical Dept., Brooklyn Rapid Transit System, Brooklyn; res., 117 Seminole St., Neponsit, N. Y.
Halls, Robert A., Elec. Draftsman and Asst. to Field Elec. Engineer, American Railways Co., Witherspoon Bldg., Philadelphia, Pa.
Halporn, Arnold D., Sales Engineer, B. F. Sturtevant Co., 135 N. 3rd St., Philadelphia, Pa.
Hansen, Bert A., Sales Engineer, Cutler-Hammer Mfg. Co., 50 Church St., New York, N. Y.
Harbert, William Henry, Electrical Engineer, Federal Mining & Smelting Co., Hailey, Idaho.
Hasegawa, Keizo, Electrical Engineer of Japanese Government Railways, Metropolitan Bldg., 1 Madison Ave., New York.
*Havens, Charles B., Asst. Electrical Engineer, Mountain States Tel. & Tel. Co.; res., 3605 W. 32nd Ave., Denver, Colo.
Hay, William J., Electrician, Duquesne Light Co.; res., 2827 Webster Ave., Pittsburgh, Pa.
Hempsey, Charles E., Equipment Inspector, The Maintenance Co., New York; res., 560, 11th St., Brooklyn, N. Y.
Henderson, Charles W., Asst. Professor of Electrical Engineering, Syracuse University; res., 712 Livingston Ave., Syracuse, N. Y.
Henderson, Horace W. W., Asst. Civil Engineer , Air Ministry, C. M. E. E. Dept., Air Ministry, 6 Portman Square, London, England.
Hix, Dolph G., Division Equipment Inspector, Western Union Telegraph Co., 800 Transportation Bldg., Atlanta, Ga.
*Hoffman, Edward L., Electrical Engineer, Adams-Beatty-Francois Corp.; res., 5613 Calument Ave., Chicago, Ill.
Hofstetter, Carl F., Designing Engineer, Wagner Electric Mfg. Co.; res., 5339 Vernon Ave., St. Louis, Mo.
Horle, Lawrence C. F., Expert Radio Aide, Navy Department, Washington, D. C.
*Hotchkiss, Fred W., Sales Engineer, Electric Machinery Co., Minneapolis, Minn.
*Hughes, Calvin T., Asst. Electrical Engineer, Connecticut Light & Power Co., Waterbury, Conn.
Hughes, Martin C., Foreman of General Laboratory, Test. Dept., N. Y. Edison Co., New York; res., 14 Cobb Place, Corona, N. Y.
Hulatt, H., Manager of Telegraphs, Grand Trunk Railway, Montreal, Quebec, Canada.
*Hyatt, Sidney M., Engineer, Hydraulic Dept., Allis-Chalmers Mfg. Co., Milwaukee; res., 537 68th Ave., West Allis, Wis.
*Kaufman, George A., Electrical Engineering Asst., Carnegie Steel Co., Munhall; res., 6722 Church St., Ben Avon, Pa.
*Keesling, Hector, Supt., Electrical Construction, Pacific Gas & Electric Co., 445 Sutter St., San Francisco, Cal.
*Kleist, Walter A., Student, Univ. of Washington; res., 4504-16th Ave. N. E., Seattle, Wash.
*Klumbach, Hampton R., Draftsman, Halcomb Steel Co.; res., 606 Walnut Ave., Syracuse, N. Y.
*Koonsman, Harold D., Layout Draftsman, Detroit Edison Co.; res., 181 Commonwealth Ave., Detroit, Mich.
*Kurtz, Edwin B., Asst. Professor of Electrical Engineering, Iowa State College, Ames, Iowa.
Lewis, James Porcher, Alabama Power Co., Birmingham, Ala.
*Locke, Edwin A., Elec. Draftsman & Designer, Charles H. Tenney & Co., Boston; res., 25 Somerset St., Belmont, Mass.

Lubcke, Charles M., Designer, American Nitrogen Products Co., 2215 N. 59th St., Seattle, Wash.
Magee, James F., Chief Electrician, State Homeopathic Hospital, Allentown, Pa.
Maggi, Guy J., Inside Trouble Man, New York Telephone Co.; res., 317 East 89th St., New York, N. Y.
*Mathes, Robert Carl, Engineer in Research Branch, Western Electric Co., 463 West St., New York, N. Y.
Mac Alister, Alexander G., Asst. Estimating Engineer, Philadelphia Electric Co., Philadelphia, Pa.; res., 580 Federal St., Camden, N. J.
McArthur, A. W. C., Cable Electrician, Messrs. W. T. Henley's Telegraph Works, Ltd., N. Woolwich; res., 6 Hereford Road, Wanstead, Eng.
McCartin, James W., Electrical Draftsman, Albert C. Wood, 1203 Stock Exchange Bldg., Philadelphia, Pa.
McClure, Edward W., Switchboard Operator, Oneida Plant, Utah Power & Light Co., Preston, Idaho.
*McDowell, Hamilton E., Electrician, Lehigh Valley Power & Light Co., Allentown; University Club, Bethlehem, Pa.
*McElhose, Irving H., Adirondack Electric Power Corp., Utica; res., 136, 2nd St., Ilion, N. Y.
Merkel, Oswald H., Power Clerk, Ludlow Mfg. Associates, Ludlow, Mass.
*Meyer, Charles C., Student, University of Penn.; res., 49 W. Ashmead Place North, Philadelphia, Pa.
*Miller, Claude A., Supt. of Line Dept., Puget Sound Traction, Light & Power Co.; res., 403 So. 51st St., Tacoma, Wash.
Moore, Austin Wilford, Editor, Testbook Dept., International Correspondence Schools; res., 63 W. Parker St., Scranton, Pa.
Moore, Raymond P., Engineer, Buffalo General Electric Co.; res., 792 Ashland Ave., Buffalo, N. Y.
Moser, Harry W., Electrical Engineer, Plant Engg. Dept., American International Shipbuilding Corp., Hog Island; res., 4521 N. 13th St., Philadelphia, Pa.
*Muelleman, Joseph P., Student, Armour Institute of Technology; res., 1460 S. Jefferson St., Chicago, Ill.
Nairn, John M., Power Salesman, Duquesne Light Co.; res., 1306 Allegheny Ave., N. S. Pittsburgh, Pa.
*Nelson, Embert C., Test Dept., General Electric Co.; res., 159 Barrett St., Schenectady, N. Y.
*Nethercut, Donald W., Distribution Engineer, Richland Public Service Co., 10 So. Park St., Mansfield, Ohio.
*Norman, Earl E., Construction Foreman, General Electric Co., Atlanta, Ga.
Northrop, Howard, Chief Electrician, Jagueyal Factory, Cuba Cane Sugar Corp., Central Jagueyal, Prov. Camaguey, Cuba.
*Novak, Frank L., Asst. to President, Charles Cory & Son, Inc., 290 Hudson St., New York, N. Y.
Oehlschlager, William A., Electrician, Pennsylvania R. R. Co.; res., 41 Prospect St., Trenton, N. J.
*Pelaez C., Ernesto, Laboratory Asst., Willard Storage Battery Co., Cleveland, Ohio; res., Calle de Narino No. 2, Medellin, Colombia, S. A.
*Poe, Charles R., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
*Pomeroy, William C., Instructor in Physics, Univ. of California; res., 2333 Channing Way, Berkeley, Cal.
Porges, Edward D., Sales Engineer, Federal Sign System, 224 N. Meridian St., Indianapolis, Ind.
Porter, H. L., Dist. Manager, Verne W. Shear & Co., 1202 Illuminating Bldg., Cleveland, Ohio.
*Predock, Norvill H., Engineer, St. Louis Car Co., St. Louis; res., 3101 Walter Ave., Maplewood, Mo.
Rannels, Samuel Clyde, 108 Doyle Ave., Providence, R. I.
*Ross, Russell H., Student, Univ. of Minnesota, Minneapolis; res., 727 East 1st St., Duluth, Minn.
*Rowand, Alfred M., Student, Ohio Northern University; res., 522 N. Johnson St., Ada, Ohio.
*Schlenk, Hugo, Jr., Student, University of Minnesota; res., 312, 18th Ave. S. E., Minneapolis, Minn.
*Schwartz, Emil E., Electrical Inspector, Interborough Rapid Transit Co.; res., 351 E. 72nd St., New York, N. Y.
*Sechrist, Gilbert H., Instructor in Electrical Engineering, Louisiana Industrial Institute, Ruston, La.
*Shaw, Harold N., Electrical Engineer, A. O. Smith Corp.; res., 1466, 27th St., Milwaukee, Wis.
*Smith, Winfred W., Research Investigator, N. J. Zinc Company (of Pa.); res., 552 Franklin Ave., Palmerton, Pa.
*Smithson, Earl W., Duplex Lighting Works, General Electric Co., 6 West 48th St., New York, N. Y.
Smythies, Reginald Eric, General Manager, Lincoln Electric Co. of Canada, Ltd., 1109 Temple Bldg., Toronto, Ont.
*Sporn, Max E., Chief Tester, Small Motor Dept., Crocker-Wheeler Co., Ampere, N. J.; res., 63 Canal St., New York, N. Y.
*Sporn, Philip, Office Engineer, Construction Dept., Consumers Power Co.; res., 212 7th St., Jackson, Mich.
*Stacy, John D., Asst. Engineer, Lightning Arrester Engg. Dept., General Electric Co.; res., 27 Ashley St., Pittsfield, Mass.
Stanford, Leland H., Major, Signal Corps, U. S. A., Dept. Signal Office, Fort San Houston, Texas.
*Storm, Hans O., Student, Leland Stanford Jr. University, Stanford University, Cal.
*Strassner, Frank J., Transmission Engineer, Western Electric Co.; New York, N. Y.; res., 716 Clifton Ave., Newark, N. J.
*Stuart, Virgin N., Valuation Engineer, with F. C. Hamilton, 60 Wall St., New York, N. Y.
Sudderth, D. Glenn, Jr., Sales Engineer, Westinghouse Elec. & Mfg. Co., 1333 Candler Bldg., Atlanta, Ga.
Sumner, William A., Designing Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 835 Rebecca Ave., Wilkinsburg, Pa.
*Swisher, Arthur W., Chief Supervisor, Stores & Material Control, Div. No. 1, American International Shipbuilding Co., Hog Island, Pa.
Tanner, Edwin L., Electrical Engineer, Columbia Graphophone Mfg. Co.; res., 27 Denver Ave., Bridgeport, Conn.
*Thomas, Milton A., Asst. in Engineering Dept., The Connecticut Light & Power Co.; res., 42 Concord St., Waterbury, Conn.
*Trawick, Henry P., Testing Dept., General Electric Co.; res., 855 Union St., Schenectady, N. Y.
*Utley, Romeyn L., Cadet Engineer, Public Service Railway Co.; res., 107 Halsey St., Newark, N. J.
*Warner, Harry O., Instructor in Charge of Electrical Engg., George Washington University, 2023 G. St. N. W., Washington, D. C.
*Wehle, Paul G., Geographical Secretary, Interchurch World Movement, 894 Broadway, New York; res., 112 Grand Ave., Jamaica, N. Y.
West, Harry R., Instructor in Electrical Engineering, Univ. of Pennsylvania; res., 5114 Spruce St., Philadelphia, Pa.
Whitcomb, Arthur J., Testing Engineer, Steel & Tube Co. of America; res., 11313 Forest Ave., Chicago, Ill.
Whiting, Arthur C., Chief Engineer, Hotel Astor, Broadway & 44th St., New York, N. Y.
Withers, Francis P., Manager, Engineering Dept., Central Electric Company, 316 S. Wells St., Chicago, Ill.
*Whittle, Horace, Engineer, Western Electric Co., 463 West St.; res., 825 W. 179th St., New York, N. Y.
Wipperman, Frederic B., Research Dept., Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Mo.
Yost, Charles H., Laboratory Asst., General Electric Co., 309 W. 8th St., Erie, Pa.
Young, Levi F., Asst. Laboratory Foreman, Kansas City Light & Power Co., 2110 Walnut St., Kansas City, Mo.
Zeiger, Louis B., General Foreman, Standardizing Laboratory, Brooklyn Edison Co.; res., 1262, 54th St., Brooklyn, N. Y.
*Zippler, William N., Student, University of Pennsylvania, Philadelphia, Pa.; res., 33 High St., Woodbury, N. J.
Total 139
*Former enrolled student.

ASSOCIATES REELECTED FEBRUARY 18, 1920

Baker, Henry S., In Charge of Detail Apparatus, Ontario Power Co.; res., 52 Main St., Niagara Falls, Ont.
McKibbin, Robert H., Electrical Engineer, Southwest Cotton Co., Phoenix, Arizona.

MEMBERS ELECTED FEBRUARY 18, 1920

Bewlay, Henry F., Designing Engineer, Ideal Electric & Mfg. Co., Mansfield, Ohio.
Hill, Harry Charles, Commercial Engineer, Westinghouse Electric International Co.,Union Bldg., Bund & Canton Road, Shanghai, China.
Jensen, J. L. W. V., Chief Engineer, Copenhagen Telephone Co.; res., Amicisvej 16, Copenhagen V, Denmark.
Juhnke, Paul B., Chief Load Dispatcher, Commonwealth Edison Co.; res., 5403 Lakewood Ave., Chicago, Ill.
Lundell, Carl H., Asst. Engineer, Astoria Iron Works, Astoria; res., 507 East 46th St., North, Portland, Ore.
Walther, Harry L., Division Manager, California-Oregon Power Co., 216 W. Main St., Medford, Ore.

TRANSFERRED FEBRUARY 18, 1920

To Grade of Member

ALDRIDGE, A. P., Engineer-in-charge, Waipori Falls Power Station, Dunedin, N. Z.
BURCHER, REGINALD H., Outside Plant Engineer, American Tel. & Tel. Co., New York, N. Y.
DANE, LOUIS P., Asst. Chief Engineer, Railway & Industrial Engineering Co., Greensburg, Pa.
DAVIDSON, WARD F., Instructor in Electrical Engineering, University of Michigan, Ann Arbor, Mich.
HARDY, NORMAN G., Chief Mechanical and Electrical Engineer, The Arizona Copper Co. Ltd., Clifton, Ariz.
HOGAN, JOHN V. L., Manager, International Radio Telegraph Co., New York, N. Y.
LENNARD, WILLIAM H., Electrical Supt., The Haughton Elevator & Machine Co., Toledo, O.
OAKES, CHARLES E., Associate Electrical Engineer, Bureau of Standards, Washington, D. C.
OWEN, ALEXANDER C., Assistant Electrical Engineer, Public Works Department, Wellington, N. Z.
PIERCE, GUY C., Vice-President and General Manager, Northwestern Electric Co., Portland, Ore.
SIMPSON, FRANK, Manager St. Louis District, Pittsburgh Transformer Co., St. Louis, Mo.
WURTS, THOMAS C., Heavy Traction Section, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

To Grade of Fellow

BALL, JOHN D., Vice-President and Dean, School of Engineering of Milwaukee, Milwaukee, Wis.
GREEN, CHARLES M., Research Laboratory, General Electric Co., Lynn, Mass.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at a meeting held on February 16, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

BLISS, LOUIS D., President, Bliss Electrical School, Takoma Park, Washington, D. C.
GRAY, CLYDE D., Electrical Engineer, J. G. White Engineering Corp., New York, N. Y.
WALLACE, JOHN N., Engineer in Australasia, Western Electric Co., Ltd., Wellington, N. Z.

To Grade of Member

ACKLAND, EUSTACE W., Managing Director, National Electrical & Engineering Co. Ltd., Wellington, N. Z.
BOYKIN, RICHARD M., Vice-President and General Manager, North Coast Power Co., Portland, Ore.
CANDY, ALBERT M., General Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
GASKILL, WALTER W., Consulting and Sales Engineering, Boston, Mass.
GILLESPIE, FONTAINE M., Chief Operating Engineer, Riegos y Fuerza del Ebro, Barcelona, Spain.
GUILFORD, WILLIAM S., Director, Griffin Engineering Co. Ltd., Capetown, S. Africa.
HAYES, CLIFTON R., Engineering Manager, Charles H. Tenney & Co., Boston, Mass.
HENKLE, Joseph C., Supt. Meters & Construction, Portland Railway, Light & Power Co., Portland, Ore.
HOFFMAN, CHARLES B., Assistant Professor of Electrical Engineering, University of Cincinnati, Cincinnati, O.
KARTAK, FRANZ A., Professor of Electrical Engineering, School of Engineering of Milwaukee, Milwaukee, Wis.
LAMB, GILBERT C., Electrical Engineer, Engineering Div., E. I. du Pont de Nemours & Co., Wilmington, Del.
MAVITY, VICTOR T., Electrical Engineer, Braden Copper Co., Rancagua, Chile, S. A.
NOYES, JOHN D., Sales Engineer, Detroit Edison Co., Detroit, Mich.
PECK, EMERSON P., Gen'l Supt., Elec. Dept., Utica Gas & Electric Co., Utica, N. Y.
THOMAS, GEORGE N., Electrical Engineer, Canadian General Electric Co. Ltd., Toronto, Ont.
WERWATH, OSCAR, President, School of Engineering of Milwaukee, Milwaukee, Wis.

APPLICATION FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member, objecting to the election of any of these candidates should so inform the Secretary before March 31, 1920.

Adams, Harvey P., McAllen, Texas.
Adams, Howard H., Philadelphia, Pa.
Adams, Myron W., Millbury, Mass.
Aitchison, Willard L., New York, N. Y.
Anderson, E. W., Evanston, Ill.
Anderson, William Kingston, R. I.
Andrews, Fred A., Hoosac Tunnel, Mass.
Antoniono, Caesar, Chicago, Ill.
Arledge, George H., Washington, D. C.
Arnold, Oscar M., New York, N. Y.
Aslaniar, Coffing W., Boston, Mass.
Bailey, George N., Worcester, Mass.
Ball, F. Widmer, Toronto, Ont.
Bangs, Philip C., Atlanta, Ga.
Barcus, Miner, Newark, N. J.
Barden, Harold E., Los Angeles, Cal.
Barnes, Stanley M., Detroit, Mich.
Barney, Howard S., Kennett Square, Pa.
Barrett, Charles E., Louisville, Ky.
Barron, Edward F., New York, N. Y.
Barry, Thomas A., Boston, Mass.
Bayle, Russell M., E. Pittsburgh, Pa.
Beard, Harry F., Hog Island, Pa.
Beechinson, Herbert M., New York, N. Y.
Bender, Louis V., Cambridge, Mass.
Benjamin, Webster W., Boulder, Colo.
Bergen, Harold B., New York, N. Y.
Binder, Albert A., (Member), St. Louis, Mo.
Blackwell, William I., Worcester, Mass.
Bland, Henry, Hawthorne, Illinois
Blair, Wayne C., Kansas City, Missouri.
Blue, Frederick R., Brooklyn, N. Y.
Bodey, Norman A., Reading, Pennsylvania.
Bradley, Francis H., New Haven, Conn.
Bradner, James P., Washington, D. C.
Broe, Edgar P., New York, N. Y.
Broodhun, Carl P., Wilkes-Barre, Pa.
Brooks, Forrest E., New York, N. Y.
Brown, Lewis R., (Member), Newark, N. J.
Brown, Wendell S., (Member), Providence, R. I.
Bryan, Cyril K., Schenectady, N. Y.
Burnett, William, Jr., Frankfort, Ill.
Burrows, Walter G., New York, N. Y.
Carlson, Carl F., Brooklyn, N. Y.
Carnachan, Robert S., Washington, D. C.
Carpenter, Leslie S., New York, N. Y.
Champlin, Franklin J., Pittsfield, Mass.
Chapman, V. J., Schenectady, N. Y.
Chesnut, Edward F., Toronto, Ont.
Chute, Norman T., Hartford, Conn.
Clark, Henry W., Washington, D. C.
Clarke, Albert M., Toronto, Ont.
Cleary, Leo H., Washington, D. C.
Cleary, William J., New York, N. Y.
Clements, Chauncey H., New Haven, Conn.
Cleon, Hyman, Washington, D. C.
Cobb, Cecil C., Oklahoma City, Okla.
Collins, Everett B., Worcester, Mass.
Collins, Raymond P., New Haven, Conn.
Comstock, William W., New York, N. Y.
Conklin, Silas H., Washington, D. C.
Cooper, Geoffrey T., Boston, Mass.
Coupland, Richard C., Gloucester, Mass.
Cowles, Willard B., Meriden, Conn.
Cox, Louis T., New York, N. Y.
Creasey, John W., Kansas City, Mo.
Cromwell, George F., Milwaukee, Wis.
Crump, Samuel L., Denver, Colo.
Cuff, Paul S., New York, N. Y.
Curtis, Egbert H., (Member), New York, N. Y.
Daniels, Thomas E., Ogden, Utah.
Darling, Charles W., Sydney, C. B. Canada.
Davies, Stanley F., (Member), New York, N. Y.
Davis, Albert T., Greensburg, Pennsylvania.
Davis, C. I., Evanston, Ill.

Dennison, Allan, Nobel, Ontario.
De Nyse, Charles R., Jr., New York, N. Y.
De Penning, Victor H., Portland, Oregon.
Dodge, John W., San Francisco, Cal.
Doesch, Louis A., Hoboken, N. J.
Dorpat, Martin H., Milwaukee, Wis.
Dortch, G. L., Little Rock, Ark.
Drake, Charles P., La Crosse, Wis.
Duncan, P. M., W. Allis, Wis.
Duncan, W. Bryan, Bakersfield, Cal.
Eales, Malcolm A. L., Worcester, Mass.
Ebaugh, John H., Denver, Colo.
Edgerton, Rupert, L., New Haven, Conn.
Edwards, John H., (Member), Huntington, W. Va.
Ehlers, Paul, Bettendorf, Iowa.
Elebash, Karl S., Tuscaloosa, Alabama.
English, Charles L., Ansonia, Conn.
Eshelman, Paul B., Lancaster, Pennsylvania.
Evans, James M., Fresno, Cal.
Fay, Richard D., Cambridge, Massachusetts.
Ferguson, Muirhead T., Halifax, N. S.
Ferry, James H., Washington, D. C.
Flath, Earl H., University, Alabama.
Flynn, William N., Portsmouth, N. H.
Fogelsong, Elmer B., St. Louis, Mo.
Forbes, Allan C., (Member), Chicago, Ill.
Foy, Bertrand A., Washington, D. C.
Freehafer, Fred K., Philadelphia, Pa.
French, F. D., Buffalo, N. Y.
Friend, Leonard, Toledo, Ohio.
Gaffney, Joseph F., New York, N. Y.
Garrett, Curtis L., Baltimore, Md.
Gass, Thomas A., Toronto, Ont.
Gibson, Archie B., E. Pittsburgh, Pa.
Gilchrist, Frederick W., Milwaukee, Wis.
Gillett, Francis E., Lancaster, N. Y.
Glasgow, Roy S., St. Louis, Mo.
Godshalk, Ernest L., Norristown, Pa.
Goldberg, Israel, Toronto, Ont.
Goldsman, Jack L., New York, N. Y.
Goldston, Leonard, Brooklyn, N. Y.
Gollady, Lawrence R., E. Pittsburgh, Pa.
Goodnough, Rex Eugene, Hawthorne, Illinois.
Grasle, Wesley R., Portland, Oregon
Gregory, William H., Toronto, Ont.
Hall, Albert I., Pittsfield, Mass.
Ham, Frank L., Worcester, Massachusetts.
Haman, Donald A., Brooklyn, N. Y.
Harrison, William H., New York, N. Y.
Hartman, Fred, Albert Tucker Co., W. Va.
Hartung, Arthur E., St. Louis, Mo.
Hastings, Milton B., Toronto, Ont.
Hecker, Arthur D., Hog Island, Pa.
Hemenway, Robert A., Worcester, Mass.
Henderson, John W. G., E. Pittsburgh, Pa.
Herrle, Jacob N., Jr., Brooklyn, N. Y.
Hickey, Charles E., New York, N. Y.
Hill, Clarence, Hog Island, Pa.
Hill, Harold C., Schenectady, N. Y.
Hill, Raymond P., (Member), Holyoke, Mass.
Hillegass, Herbert H., Philadelphia, Pa.
Hine, Donald F., New Haven, Conn.
Hodges, Frank E., New York, N. Y.
Hoelzle, Frank C., Camden, N. J.
Holcomb, P. J., Atlanta, Georgia.
Holihan, Thomas D., Syracuse, N. Y.
Hollidge, George M., Alameda, California.
Howe, Harvey W., (Member), Dallas, Texas.
Huff, Benjamin L., Jackson, Mich.
Hughes, Russell H., New York, N. Y.
Huyler, Rollin M., New York, N. Y.
Hymans, Frederick, New York, N. Y.
Irwin, James H., Chicago, Illinois.
James, Earl S., Oklahoma City, Okla.
Jeanne, Paul A., Denver, Colo.
Jeffery, Joseph A., (Member), Detroit, Michigan.
Jenkins, John R., New York, N. Y.
Jessen, Christian, Milwaukee, Wis.
Jones, Benson M., E. Pittsburgh, Pa.
Jones, Carl H., New York, N. Y.
Karlson, Edward V., Cincinnati, Ohio.
Kelle, Arthur C., Boston, Mass.
Kennedy, Clifford W., Worcester, Mass.
Khan, M. Ali, Schenectady, N. Y.
Kerr, David J., Canton North Carolina.
Kimball, Merrill J., Pittsburgh, Pa.
Kita, Ichimatsu, Schenectady, N. Y.
Kitt, Fred T., Seattle, Wash.
Knight, Henry A., Worcester, Mass.
Krueger, Carl H., Milwaukee, Wis.
Kuhn, Paul R., Altoona, Pa.
Kumeilike, Lorenz L., Mare Island, Cal.
Lampe, J. Harold, New Haven, Conn.
Laplaute, Ernest G., Marlboro, Mass.
La Roque, Harold B., New Haven, Conn.
Lash, Leland, E., Oklahoma City, Okla.
Laskey, William G., New York, N. Y.
Law, Clarence L., New York, N. Y.
Lawrence, Roger C., Worcester, Mass.
Laycock, Charles H., Boston, Mass.
Lee, Everett A., Schenectady, New York.
Lee, Ewe Aik, Chicago, Ill.
Legg, Joseph W., E. Pittsburgh, Pa.
Leonard, Russell E., (Member), New York, N. Y.
Lexa, George J., Milwaukee, Wis.
Lincoln, John C., Columbus, Ohio.
Littlefield. Maurice G., Lynn, Mass.
Livergood, Homer, Philadelphia, Pa.
Lockerbie, Earl M., Syracuse, N. Y.
Loos, Aldo H., Kansas City, Mo.
Loynes, Owen H., New York, N. Y.
Luke, George E., E. Pittsburgh, Pa.
Lunny, James E., New York, N. Y.
Lyon, William R., Madison, Wis.
Maddock, Edwin G., Oshawa, Ontario.
Magnuson, Axel H., (Member), Worcester, Mass.
Masek, James C., (Member), Milwaukee, Wis.
Mason, Donald T., Youngstown, Ohio.
Miller, Charles A., Tacoma, Wash.
Mitzenius, Walter L., New York, N. Y.
Moore, Charles R., New York, N. Y.
Moore, Eric M., Portage, Wash.
Munoz, Alphonz, Claymont, Del.
Murata, Motosaburo, New York, N. Y.
Myers, Alexander M., Perth Amboy, N. J.
McChesney, Robert W., Washington, D. C.
McCordick, Arthur S., Toronto, Ont.
McKerrow, Alan D., Worcester, Mass.
McLaren, Duncan L., Peterboro, Ont.
McLeer, Charles B., (Fellow), New York, N. Y.
McOrolly, Joseph, Greensburg, Pennsylvania.
Naylor, John M., Millville, N. J.
Neustedter, Walter J., Milwaukee, Wis.
Newman, Willard L., New York, N. Y.
O'Hara, George D., (Member), San Francisco, Cal.
Oldham, Edward C., Worcester, Mass.
O'Neill, Frank H., Fairmont, W. Va.
Osburn, William, Cincinnati, Ohio.
Overbey, Frank E., New York, N. Y.
Packard, Ansel A., Middletown, Connecticut.
Parmer, Marion C., Wheeling, W. Va.
Payne, William H., Pittsburgh, Pa.
Pearson, Harold J. C., Atlanta, Ga.
Pender, Paul S., Milwaukee, Wis.
Pennington, John F., Atlanta, Ga.
Perkins, E. Everett, Jr., E. Pittsburgh, Pa.
Perkins, Guy S., Buffalo, N. Y.
Petrie, Albert E., New York, N. Y.
Pette, Allen D., Chicago, Ill.
Phelps, Leverne R., Dunkirk, N. Y.
Phillips, Charles O., Philadelphia, Pa.
Phinney, Harry L., San Francisco, Cal.
Pigman, George R., (Member), New York, N. Y.
Plaisance, Stanley F. X., Chicago, Ill.
Polachek, Zoltan H., New York, N. Y.
Pope, Harry M., New York, N. Y.
Postles, Findlay J., New York, N. Y.
Poston, Virgil, New York, N. Y.
Powell, Joel W., San Francisco, Cal.
Powell, Roland A., Ridgway, Pa.
Prosser, William E., St. Louis, Mo.
Purinton, Ralph B., Chicago, Ill.
Ranges, John E., New York, N. Y.
Rathke, C. George, Waterbury, Conn.
Reich, Walter J., Schenectady, N. Y.
Reichenstein, Herman, Elizabethport, N. J.
Rhys, Cyril O., (Member), Beverly, Mass.
Richardson, Frank D., (Member), New York, N. Y.
Richardson, Simeon W., Washington, D. C.
Rives, Tom C., Montgomery, Ala.
Rocchetti, Joseph, Winnipeg, Man.
Roberts, Clinton V., Erie, Pennsylvania.
Rosenzweig, Fred M., Chicago, Ill.
Rusmisell, Charles T., McDowell, W. Va.

Rutan, Everett J., New York, N. Y.
Ryan, Clarke L., Omaha, Neb.
Sawyer, Lee A., New York, N. Y.
Sawyer, Leon G., Brooklyn, N. Y.
Schectell, Joseph, Boston, Mass.
Scheffer, Robert E., Schenectady, N. Y.
Schelleng, John C., New York, N. Y.
Schwarberg, Harry John, Cincinnati, Ohio.
Selzer, Carl A., Philadelphia, Pa.
Shaffer, Irwin, Akron, Ohio.
Shannonhouse, George G., Jr., (Member), Detroit, Mich.
Sheadel, James B., Anderson, Ind.
Sinner, Harry C., Philadelphia, Pa.
Smith, Harry A., (Member), Atlanta, Ga.
Smith, J. Frank, Philadelphia, Pa.
Smith, John F., New York, N. Y.
Spates, Thomas G., New York, N. Y.
Sprague, Arthur B., Worcester, Mass.
Stayner, Charles M., Farmington, Utah.
Stein, Rudulph H., New York, N. Y.
Stier, H. Douglas, Chicago, Ill.
Stone, J. Waldo, New York, N. Y.
Sturtevant, Benjamin J., Milwaukee, Wis.
Suydam, William H., Jr., New York, New York.
Templeman, Daniel R., Worcester, Mass.
Terrell, Phillip A., Birmingham, Ala.
Teschner, Albert, Bayonne, N. J.
Thomas, James W., (Fellow), New York, N. Y.
Thompson, Thomas C., Chicago, Ill.
Tobiessen, Emanuel, W. Allis, Wis.
Tornquist, Earl L., Waukegan, Ill.
Townsend, Wisner R., New York, N. Y.
Trojan, Ervin J., Chicago, Ill.
Truman, Joseph K., Canyon Ferry, Mont.
Tyler, Charles H., S. Charleston, W. Va.
Van Horn, Alfred R., Plainville, Conn.
Van Thun, James R., Hog Island, Pa.
Voss, Henry L., Terre Haute, Ind.
Walter, Hollis, Brooklyn, N. Y.
Waterhouse, James K., New York, N. Y.
Wegel, Raymond L., New York, N. Y.
Welch, Paul V., New York, N. Y.
Weller, Clifford T., Schenectady, N. Y.
White, Myron B., (Member), Ampere, N. J.
Whitehurst, Roland, New York, N. Y.
Whyte, Thomas G., (Member), Lynn, Mass.
Wilcox, Harry K., Paterson, N. J.
Willey, Charles E., (Member), Louisville, Ky.
Williams, F. George, McKees Rocks, Pa.
Wills, Harry L., Atlanta, Ga.
Witt, Stanley, St. Louis, Mo.
Woellmer, Louis A., New York, N. Y.
Wolf, Wyatt H., New York, N. Y.
Woodman, Arthur P., Evanston, Ill.
Woodward, Alan A., Toledo, Ohio.
Wright, Fred E., Mt. Vernon, N. Y.
Wu, Wei-Yoh, New York, N. Y.
Young, Russell, Philadelphia, Pa.
Zinckgraf, Raymond G., New York, N. Y.
Total 308.

Foreign

Goodwin, Albert G. T., (Member), Port Pirie, S. Aus.
Hada, Tsunezo, Sukegawa, Ibaragiken, Japan.
Ishida, S., Nagoya, Japan.
Jones, Ernest, (Member), Havana, Cuba.
Kasai, Tokyo, Japan.
Mitsuda, R., (Fellow), Tokyo, Japan.
Nakazawa, Shinji, Tokyo, Japan.
Robinson, Isaac R., Wellington, New Zealand.
Total 8

STUDENTS ENROLLED
FEBRUARY 18, 1920

11022 Kennedy, Walter A., Wentworth Institute.
11023 Cook, Lee E., Texas A. & M. College
11024 Way, Howard E., Penn. State College
11025 Mugg, Fred H., Leland Stanford Jr., University
11026 Linn, Frank C., Leland Stanford Jr., University
11027 Browning, Clarence L., Kansas State Agricultural College
11028 Peterson, Robert M., Worcester Polytechnic Institute
11029 Wolking, Clifford G., University of New Mexico
11030 Worthington, Leonard F., Bucknell University
11031 Egner, Milton D. M., Johns Hopkins University
11032 Wagner, Hiram J., Bucknell University
11033 Robbins, James E., Bucknell University
11034 Weaver, Torrence E., Penn. State College
11035 Russell, Howard C., Case School of Applied Science
11036 Churchill, Charles H., Cornell University.
11037 Davis, Rowland F., Cornell University
11038 Bass, Percy B., University of Virginia
11039 Coleman, James O'R., University of Virginia
11040 Wolking, Clifford G., University of New Mexico
11041 Orth, Arthur D., Rose Polytechnic Institute
11042 Bryan, William, Rose Polytechnic Institute
11043 Meadows, William H., Jr., Rose Polytechnic Institute
11044 Stone, Frank M., Rose Polytechnic Institute
11045 Kessler, Harold L., Rose Polytechnic Institute
11046 Heubel, Frank N., Rose Polytechnic Institute
11047 Stevenson, Peter J., Penn. State College
11048 Avrit, Roy C., Oregon State Agricultural College
11049 Doukas, Samuel J., Oregon State Agricultural College
11050 Sherman, Donald C., Ohio Northern University
11051 Gaines, Vincent S., Washington University
11052 Tsu, Fong Chang, Massachusetts Institute of Technology
11053 Martin, Curtis R., University of Minnesota
11054 Miller, Joe D., Lewis Institute
11055 Mangney, Elmer J., University of Minnesota
11056 Kline, Frank W., University of Minnesota
11057 Miller, Andrew, University of Minnesota
11058 Firehammer, Paul B., Tri-State College
11059 Brown, Reu W., Oklahoma A. & M. College
11060 Calame, Carroll E., Oklahoma A. & M. College
11061 Coleman, Lester L., Oklahoma A. & M. College
11062 Courtney, Mahlon C., Oklahoma A. & M. College
11063 Gray, Earle W., Oklahoma A. & M. College
11064 Hollingshead, E. C., Oklahoma A. & M. College
11065 Hinson, Marcus W., Oklahoma A. & M. College
11066 Folk, Joe W., Oklahoma A. & M. College
11067 Kratzer, Roy E., Oklahoma A. & M. College
11068 Larner, Ray A., Oklahoma A. & M. College
11069 Myers, George M., Oklahoma A. & M. College
11070 Sadlo, Edward C., Oklahoma A. & M. College
11071 Soule, Clayton E., Oklahoma A. & M. College
11072 Tabor, Paul S., Oklahoma A. & M. College
11073 Wood, Paul H., Oklahoma A. & M. College
11074 Zimmerman, Lloyd, Kansas State Agricultural College
11075 Treadway, Alexander H., University of Arkansas
11076 Talbot, John C., Stevens Institute of Technology
11077 Brewer, Richard W., University of Wisconsin
11078 Bonner, Harry H., Drexel Institute
11079 Kepner, Homer S., Drexel Institute
11080 Nichols, John J., Drexel Institute
11081 Matthews, Alfred H., Drexel Institute
11082 Andrews, Clifton J., School of Engineering of Milwaukee
11083 Chie, Joe H., School of Engineering of Milwaukee
11084 Ellison, Carl E., School of Engineering of Milwaukee
11085 Goljenboom, George, School of Engineering of Milwaukee
11086 Hecker, Walter J., School of Engineering of Milwaukee
11087 Lathrop, Philip O., School of Engineering of Milwaukee
11088 Olsen, Evin A., School of Engineering of Milwaukee
11089 Poage, Emery M., School of Engineering of Milwaukee
11090 Reynolds, Paul E., School of Engineering of Milwaukee
11091 Schrodt, Roy O., School of Engineering of Milwaukee
11092 Ball, Wilmot C., Johns Hopkins University
11093 Upholl, Leslie S., Union College
11094 Culverhouse, P. William, Union College
11096 Wickersham, Harry P., Leland Stanford Jr. Univ.
11097 Woodbury, David O., Leland Stanford Jr. University
11098 Lunge, George S., University of Washington
11099 Inouye, Isamu, University of Washington
11100 Oberle, Henry, Montana State College
11101 Coney, Tong, Tri-State College
11102 Lawrence, Eugene C., Tri-State College
11103 Albertson, William C., Jr., Lafayette College
11104 Hartman, John R., Union College
11105 Hollinger, Abraham L., Jr., Throop College of Tech.
11106 Case, Henry R., Throop College of Technology
11107 Manning, Allen M., Oregon Agricultural College
11108 McGeoch, Rae, Toronto Central Technical School
11109 Klippel, Earl F., Washington University
11110 Spofford, Franklin D., University of Illinois
11111 Sturm, Clark H., University of Illinois
11112 Crane, Carl C., University of Michigan
11113 Stebbins, Fred G., Union College
11114 Becker, Hugo E., Leland Stanford Jr. University
11115 Strain, Herbert G., Leland Stanford Jr. University
11116 Harman, C. N., West Virginia University
11117 Frum, John M., West Virginia University
11118 Daniels, Harold C., West Virginia University
11119 Brady, Joseph J., Cooper Union
11120 Brown, Kilder J. T., A. & M. College of Texas

11121 Benezra, Henry, University of Washington
11122 Freeman, Newell L., Washington University
11123 Pilkington, John H., University of Michigan
11124 Creighton, Charles P., McGill University
11125 Cook, Ellsworth D., Union College
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PERSONAL

Robert T. Lozier, Consulting Engineer, announces that he has resumed his Industrial Consultant practise, in room 2636, Woolworth Building, New York, N. Y.

Frederic Nicholas, formerly Contributing Editor of the *Electrical World*, has been appointed Secretary of the Electrical Manufacturers' Council. It is hoped to open permanent offices for the Council in New York as soon as a suitable location can be found.

Murray C. Beebe, formerly Professor of Electrical Engineering at the University of Wisconsin, and recently associated with the Western Electric Company, New York, has resigned to become Chief Engineer of the Wadsworth Watch Case Company, Dayton, Kentucky.

Arthur Raymond Nissar, Professor of Electrical Engineering, Central Technological Institute, Byculla, Bombay, India, is shortly proceeding to Europe on leave. His address there for a period of about six months will be c/o Messrs. Thos. Cook & Son, Ludgate Circus, London, England.

Louis Barnett has accepted the position of Sales Engineer with the Multiple Electric Products Co., Inc. of New York. He is a graduate of the Massachusetts Institute of Technology '09 and for the last ten years has been associated with the American Sugar Refinery of Brooklyn as Departmental Engineer, where he has had wide and varied experience with electrical apparatus.

B. J. Grigsby, Vice-President of the Anderson Electric Specialty Co., announces that the corporate name of this company has been changed to Anderson Electric & Equipment Co. There is no change either in the officers or the company's organization; the change has solely been made to render the corporate name more descriptive of the character of the products manufactured by the company and to eliminate the world "Specialty," which did not properly describe the Anderson lines.

Sergis P. Grace, who has been assistant to the Vice President of the New York Telephone Company, has accepted the position of Assistant to the President of the Standard Chemical Company, Pittsburgh, producers of Radium, Vanadium, and Uranium. Mr. Grace has had a long and varied experience in engineering work, especially in the telephone field, in which he has been since 1896. First with the Detroit Telephone Company, he went in 1898 to New Orleans as chief engineer and operating manager of the Peoples' Telephone Company of New Orleans. Following that work he became connected with the Southwestern Telephone & Telegraph Company, of Texas and Arkansas, which he left to become the chief engineer of the Inter-State Telephone Company of New Jersey. In 1902 he joined the engineering staff of the American Telephone & Telegraph Company, which had charge of the design of all Bell Telephone apparatus and methods throughout the country. Leaving the service of the Bell Telephone system in 1913, he engaged in private engineering work in New York City; but in December, 1915 he became again connected with the Bell Telephone system, which at that time included the New York Telephone Company. In December, 1919 he appeared as a witness for the New York Telephone Company before the New Jersey Commission.

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Indianapolis-Lafayette	J. Lloyd Wayne	D. C. Pyke, Public Service Commission, State House, Indianapolis, Ind.
Ithaca	Alexander M. Gray	John G. Pertsch, Jr., Cornell Univ., Ithaca, N. Y.
Los Angeles	Clem A. Copeland	R. W. Sorensen, Throop College of Technology, Pasadena, Cal.
Lynn	A. K. Warren	Fred E. Ewart, General Electric Company, West Lynn, Mass.
Madison	C. M. Jansky	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Milwaukee	H. P. Reed	F. J. Mayer, Wisconsin Tel. Co., Milwaukee, Wis.
Minnesota	Fred Dustin	Leo H. Cooper, 200 Builders Exch., Minneapolis, Minn.
New York	H. W. Buck	H. A. Pratt, W. E. & M. Co., 165 Broadway, New York
Panama	Wm. T. O'Connell	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	C. E. Clewell	Ross B. Mateer, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.
Pittsburgh	J. G. Carroll	W. L. Shafer, Rm. 522, 416-7th Ave., Pittsburgh, Pa.
Pittsfield	R. E. Wagner	N. F. Hanley, Gen. Elec. Co., Pittsfield, Mass.
Portland, Ore.	E. F. Whitney	W. C. Heston, Portland Ry. Lt. & Pr. Co., Portland, Ore.
Rochester	J. W. Morrison	A. J. Schiefer, Jr., 312 E. & B. Bldg., Rochester, N. Y.
St. Louis	G. A. Waters	Stanley Stokes, Union Elec. Lt. & Pr. Co., St. Louis, Mo.
San Francisco	W. G. Vincent	A. G. Jones, 809 Rialto Building, San Francisco, Cal.
Schenectady	C. S. Van Dyke	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle	G. E. Quinan	W. T. Batcheller, Seattle Lt. & Pr. System, Seattle, Wash.
Spokane	J. E. E. Royer	Foster Russell, Symons Bldg., Spokane, Wash.
Toledo	W. A. Hill	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto	Ashton B. Cooper	Daniel M. Fraser, Canadian General Electric Co., Toronto, Ont.
Utah	Markham Cheever	T. A. Purton, General Electric Co., Newhouse Bldg., Salt Lake City, Utah.
Urbana	Morgan Brooks	E. A. Reid, Univ. of Illinois, Urbana, Ill.
Vancouver	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C.	Milton M. Flanders	P. A. B. Sahm, Bureau of Standards, Washington, D. C.

Total 34

LIST OF BRANCHES

Name and Location	Chairman	Secretary
Alabama Poly. Inst., Auburn, Ala.	W. W. Hill	E. E. Terry
Alabama, Univ. of, University, Ala.	J. P. Thomas	R. W. Wilkerson
Arkansas, Univ. of, Fayetteville, Ark.	J. C. Black	S. E. Hollabough
Armour Institute, Chicago, Ill.	W. M. Seyferlich	H. D. Stevers
Brooklyn Poly. Inst., Brooklyn, N. Y.	T. C. Shwab	A. H. Wehle
Bucknell Univ., Lewisburg, Pa.	H. C. Lucus	L. F. Worthington
California, Univ. of, Berkeley, Cal.	H. C. Silent	M. L. Almquist
Carnegie Inst. of Tech., Pittsburgh, Pa.	K. K. Knaell	B. C. Dennison
Cincinnati, Univ. of, Cincinnati, O.	C. S. Meyer	C. B. Hoffmann
Clarkson College of Tech., Potsdam, N. Y.	E. R. Taylor	H. C. Cohn
Clemson Agri. Col., Clemson College, S. C.	J. B. Fitzgerald	J. F. McHugh
Colorado State Agr. Col., Fort Collins, Colo.		
Colorado, Univ. of, Boulder Colo.	D. H. Rymer	Lee J. Murray
Drexel Inst., Philadelphia, Pa.		F. J. Hartmann
Georgia School of Tech., Atlanta, Ga.	R. S. Griffith	G. L. Jones
***Idaho, Univ. of**, Moscow, Idaho		
***Iowa, Univ. of**, Iowa City, Iowa		
Kansas State Agri. Col., Manhattan, Kans.	J. S. Gulledge	M. J. Lucas
***Kansas, Univ. of**, Lawrence, Kans.		
Kentucky, Univ. of, Lexington, Ky.	J. W. Coleman, Jr.	J. D. Wood
Lafayette College, Easton, Pa.	F. W. Ross	C. S. Allen
Lehigh University, S. Bethlehem, Pa.	B. R. Nevins	S. C. Townsend
Lewis Institute, Chicago, Ill.		
Maine, Univ. of, Orono, Me.	S. E. Jones	W. C. Plumer
Mass. Inst. of Tech., Cambridge, Mass.	H. B. Deal	Florence Fogler
Michigan Agri. Col., East Lansing, Mich.	R. D. Wyckoff	R. B. Kling
Michigan, Univ. of, Ann Arbor, Mich.	L. M. Ilgenfritz	Ross Gunn
Milwaukee, Eng. Sch. of, Milwaukee, Wis.	John D. Ball	J. L. Gordon
Minnesota, Univ. of, Minneapolis, Minn.	Norman Kingsley	C. L. Nelson
Missouri, Univ. of, Columbia, Mo.	A. C. Lanier	F. H. Miller
Montana State Col., Bozeman, Mont.	Jesse Flynn	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State Col., West Raleigh, N. C.	J. M. Peden	Oliver Ramsaur
North Carolina, Univ. of, Chapel Hill, N. C.	W. W. Neal	M. E. Lake
North Dakota, Univ. of, University, N. D.		
***Norwich University**, Northfield, Vt.		
Notre Dame, Univ. of, Notre Dame, Ind.	Frank Miles	Wm. L. Wenzel
Ohio Northern Univ., Ada, O.	Mark Jepson	W. A. Lynde
Ohio State Univ., Columbus, O.	C. H. Hoover	H. A. Lott
Oklahoma A. & M. Col., Stillwater, Okla.	Earl Gray	W. C. Lane
Oklahoma, Univ. of, Norman, Okla.	W. A. Kitchen	O. W. Walter
Oregon Agri. Col., Corvallis, Ore.	F. A. Roehrig	Roy Avrit
Pennsylvania State Col., State College, Pa.	E. W. Taylor	C. K. Mast
Pennsylvania, Univ. of, Philadelphia, Pa.	W. H. McIntyre	J. M. Ryan
Pittsburgh, Univ. of, Pittsburgh, Pa.	L. P. Kennedy	H. Q. Chan
Purdue University, Lafayette, Ind.	L. A. Malott	T. K. Hartley
Queen's University, Kingston, Ont.		
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. B. Raynor
Rose Poly. Inst., Terre Haute, Ind.	F. M. Stone	H. L. Kessler
Stanford Univ., Stanford University, Cal.	Aubrey Smith	H. O. Storm
Syracuse Univ., Syracuse, N. Y.	W. P. Graham	R. D. Whitney
Texas A. & M. Col., College Station, Tex.	L. E. Cook	D. D. Murphree
Texas, Univ. of, Austin, Tex.	W. J. Miller	Clyde Young
Throop Col. of Tech., Pasadena, Cal.	R. M. Otis	D. D. Smith
Virginia Poly. Inst., Blacksburg, Va.	L. D. Fry	R. W. Harvey
Virginia, Univ. of, University, Va.	C. Henderson	W. W. Boyd
Washington, State Col. of, Pullman, Wash.	A. L. Ziegler	C. B. Carpenter
Washington Univ. St. Louis, Mo.	Edw. Bowles	F. W. Schramm
Washington, Univ. of, Seattle, Wash.	G. R. Rice	McKinley Donovan
West Virginia Univ., Morgantown, W. Va.	H. J. Walls	M. Wilcoxen
Worcester Poly. Inst., Worcester, Mass.	D. T. Canfield	E. W. Bemis
Yale University, New Haven, Conn.	H. A. Haugh, Jr.	F. J. Hubbell

***Inactive at present, due to the war** **Total 62**

ECONOMICAL SUPPLY OF ELECTRIC POWER

(*Continued from page 222.*)

the practicability of electric traction in the zone under contemplation. Table II is indeed a consolidation of interesting facts and I am pleased to note that he arrives at 14,000,000 tons of coal as the amount to be saved by electric traction over-steam which is 2,000,000 tons greater than the figures I have named in an approximate preliminary study of the situation. On the other hand, I think Mr. Potter has been conservative on his estimate regarding the maintenance figures as I believe the savings here will be *much* more rather than "more" in the amount he has named.

An illness has robbed us of Mr. Storer's direct contribution to this paper, but we find his ample support in the traction field by the recent remarks he made before the Western Railroad Club, December 15, 1919. A copy of these remarks is before me. In them he refers to President Townley's paper, read before the Boston Branch of the A. I. E. E. Mr. Townley's paper was epoch-making in its insistance that the railroad man and the electrical man view the railroad problem *together* and not *apart*. Fifteen years of association between the railroad and the electrical man has brought this amalgamation. Mr. C. L. Bardo, General Manager of the New Haven road was one of the first to recognize this necessity. Mr. Bardo recognized that the requirements necessary to efficient operation by electric or steam locomotive were equal—*but opposite*! He observed that an electric engine would haul twice the tonnage for which it was designed and then apparently without rhyme or reason go out of business three weeks later. Whereas, he noted later, if the designed service duty of the electric engine was strictly adhered to it would do its work on half the coal and half the maintenance, and would double or treble its mileage per engine failure.

Quoting from Mr. Storer's paper, "Actually, electricity has been tried in every known kind of railroad service from street railways to high-speed passenger locomotives; from mining locomotives to the heaviest freight locomotives for mountain grade and tunnel service and from switching in the great classification yards to fast freight trains on trans-continental lines. In every case electricity has shown its ability to do its work as well as, and in most cases, it has done better than the steam locomotive has done and would do it."

Mr. Storer closes his paper by saying: "The big question of capacity, fuel conservation, shortage of labor and the improvement of terminals, will exert all the pressure toward electrification that the railways can stand"; all of which points to the necessity of the super-power system which should be ready to contribute its economies to such an end.

High tribute is due Mr. Torchio for his able and intensely interesting contribution regarding the relative value of water versus steam power development. Looking at his study of the situation from conservation standpoint, brings to mind certain remarks made by Mr. Frederick Darlington, whose able services rendered the War Industries Board during the war are well known and appreciated throughout the country. Mr. Darlington said:

"In the central power station business so much of the cost of service goes to pay for invested capital that it is most essential that the interest rates should be kept low which can be done only by making the investment safe, that is; by so regulating rates that principal and interest will be secured. From a national point of view, as effecting the general industrial efficiency of our manufacturing and power-consuming districts, it is relatively unimportant whether the cost of power is one mill or two mills per unit more or less than some established rate, whereas it is of vital importance for the conservation of resources, for economy of production and for general industrial efficiency that the bulk of the power used should be made by central systems as against isolated plants; therefore let us try to get our law-makers and public executives, national, state and municipal, to take the Government point of view, in other words, to think in terms of the war which are also terms of peace from a Government standpoint, and uniformly and rationally to encourage central power development, provide for a just return to capital in electric power business and grant monopolies under regulations that will foster co-ordination and interstate operations."

The point made by Mr. Torchio regarding the decreasing advantages of water powers on rivers without regulative storage, in proportion to their seasonal variation in flow and especially where their energies can be applied only to independent systems carrying low load factor, has been one, and rightly so, to discourage their development.

It is right here where care must now be used to differentiate between the past small and confined conditions as compared with the present large and unconfined conditions. Where, in the past, rivers whose energies were to be applied to a confined system, and whose load curve for one day could be superimposed upon that of the following with near coincidence, were developed for one second-foot per square mile of drainage area, these same rivers, today, are being developed for two, three and even four second-feet per square mile of drainage area, and we have arrived at this condition because of the tremendous progress made in the inter-connections of systems through the means of which extra load capacity and diversity factor are offered. Today water power development is looking quite as much, if not more, for kilowatt-hours as it is for kilowatts, and therefore the more the energy requirement and diversity factor in inter-connected systems, the greater is the opportunity for unregulated streams to pour their kilowatt-hours

into such a composite reservoir of power. This is only saying in another way what Mr. Torchio has already said.

Mr. Torchio's table consolidating a "Review of supply and consumption of coal by classes and territories, and the relation which the potential water powers bear to the amount of coal used in the United States," brings out and confirms my statement that in the east we can never expect a greater contribution from water than 10 per cent of the total power requirement, and it is to the economy of steam produced power that we must earnestly address ourselves. On the other hand, we must be as assiduous in our effort to avail ourselves to a maximum degree of the little that nature has bestowed upon us.

Of great interest comes the check by Mr. Torchio on Mr. Potter's figures of coal to be saved by the electrical operation of the railroads. As stated before, the computed horse power of locomotives in the zone under consideration is 7,000,000. Mr. Torchio shows a total saving of 94,000,000 tons, should the 50,000,000 horse power of steam locomotives in this country be turned into electrical operation. Seven-fiftieths of 94,000,000 would be 13,160,000—a figure lying between my own estimate and that of Mr. Potter's. Again, on the industrial side, Mr. Torchio shows a saving of 61,700,000 tons saved if the present plants in the country, aggregating 25,250,000 horse power, were operated from the lines of high-efficiency central stations. As the computed horse power of the zone under contemplation calls for an aggregate capacity of 10,000,000 horse power, this would accordingly indicate a saving of 10/25 of 61,700,000 or 24,500,000 tons, which added to the above figure, for the railroads, of 13,160,000 tons, makes a total saving of approximately 38,000,000 tons. Both Professor Breckenridge of Yale, Chairman of the Fuel Conservation Committee, Engineering Council, and Director George Otis Smith, head of the department of Geological Survey, have accused me of being too conservative on these savings, and I am glad to see them showing more than less.

We have discussed the generation and utilization of power. The link between its generation and utilization is transmission and distribution. Mr. Percy H. Thomas has contributed a most valuable and illuminating discussion upon this very vital factor of consideration, and it forms a most important part of this presentation. Again we see the objective brought out by Mr. Thomas in that the great base load of the super-power system must be carried by the large, high-economy steam plants supplemented by water power; peak loads and regulative features of the system being taken care of in the main, by "present large generating stations."

Mr. Thomas's comprehensive grasp of the transmission and distribution problem of the super-power zone leaves me with but one recommendation, and that is, your most careful perusal of his paper. The functioning of capacity against inductance in the respective square relation between voltage and current must commend itself to you in the matter of maintaining unity power factor for transmission. Here we see transmission economy maintained and automatic protection against the evil effect of short circuit. A point of almost fascinating interest is the one brought out by Mr. Thomas in the capacity effect on the main line between Boston and Washington to preserve continuity of high power factor and the ability to transfer power north or south without undue loss. The main line will be a veritable static condenser to the whole system, and with such excellent distribution of generating centers, magnetization will provide means of stabilizing and maintaining a constant voltage throughout the whole system.

The simplicity of construction and reduction to a minimum of the switch gear applicable to the 220,000-volt primary transmission, making use to the maximum of present equipment installed, robs the proposed new generating equipment and super lines of much complication and cost.

Mr. Thomas touches on the cost of super-power equipment to the extent of 900,000 kw., this inclusive of generating and transmission equipment up to 700 miles, and names a figure of $150,000,000. Twice that capacity, in combination with the present large plants, would go a long ways toward handling the present industrial and railroad loads in the zone named, Mr. Potter's figures for the railroad requirements being only 750,000 kw.

Mr. Austin's and Mr. Peaslee's contributions regarding the characteristics of line and insulation for high voltage transmission carry conviction. Particularly interesting is Mr. Peaslee's appeal for ruggedness in the insulator, and Mr. Austin's appeal for simplicity of construction throughout, again touching on many points brought out in Mr. Thomas's paper.

Their papers may be interpreted briefly by saying that in the department of insulation, which is second to none in importance to maintain both economy and continuity of operation, the problem is already solved. Indeed, I think that it can be well said that so great are the returns portended by such a proposed system of organized power policy, that like the great bridges built to sustain a high density of transportation, so may these trunk and tie transmission lines be built to carry their great electrical loads. Their very largeness will bring unusual factors of safety both electrical and mechanical.

With these savings in sight, and with the means at hand to effect them, these means being but the placing in operation of intensive practises long tried out and demonstrated as sound in principle—can this nation afford to be classed as one drunk with the wealth of her natural resources, and rolling in a criminal debauch of their treasure? Is it to be the Americanism of the future to permit this intolerable record of waste to go on?

It is hardly within the province of this paper, should the investigation proposed be made and confirm these projected results, to make suggestions regarding the methods of procedure looking toward the financing and construction of the regional plant required. The following points however, are significant:

1. Conservation in fuel, labor and materials reduced to money equivalents represent approximate savings of $300,000,000 per annum.

2. The highest representative engineering talent in the country agrees that the plan is entirely practical.

3. The securities which represent an investment in such a property (said property to be confined to the features of generation and inter-connecting transmissions) whether underwritten by the

a. States, or

b. Federal Government, or

c. Private Interests, or

d. Private Interests guaranteed by the states or Government will carry a low interest by virtue of their great national importance and financing should not be difficult.

4. Our northeast Atlantic seaboard is the natural finishing shop of American industry, populated with skilled labor to which should be available a cheap and reliable power and by it will be secured high-speed production for shipment in American bottoms (our Merchant Marine) to maintain our supremacy in world's trade.

5. Industrial concerns are far behind in their power requirements and a delay in a supply of electrical power to them will force them to resort to and perpetuate the present wasteful method of supplying it by plants built by themselves. The investment necessary to their motor requirements will be gladly borne by them and financed immediately.

6. The railroads in this zone are ready for electrification as only by it will capacity be increased: first by the relief from congestion of coal traffic, and second by higher speed and tractive efforts offered in the use of electrical locomotives, thus obviating the immediate necessity of disproportionate increase in track mileage and equipment. The one alternative or the other must be chosen and the right one is apparent.

The following is a summation of approximate investment cost and return for the super-power zone:

Super-Power System

(a) New machine capacity 2,700,000 kw.
High tension transmission mileage 2100

(b) Unit cost per kw. inclusive of transmission lines, $164

(c) Total cost super power system
2,700,000 × $164 = $442,800,000

Railroads

(a) Present steam horse power 7,000,000

(b) On account increased speed, traction and machine factors 100 per cent steam horse power can be replaced by 80 per cent electrical horse power
7,000,000 × 80 per cent = 5,600,000 h.p.

(c) Cost of electrical locomotives per horse power = $80(high)
5,600,000 × 80 = $448,000,000

(d) 30,000 miles (single track) to be electrified
Cost per mile $7,500
30,000 × 7,500 = $225,000,000

(e) Total cost railroads $673,000,000

Industrial Plants

(a) Total horse power 10,000,000 of which 5,000,000 to be changed to electrical drive.

(b) Cost per horse power inclusive of transformers and local distributions $25

(c) Total cost industrial plants
5,000,000 × $25 = 125,000,000

Total zone investment	$1,240,800,000
Total savings per annum	300,000,000
Average return on investment	24 per cent

1. W. L. R. EMMET

Large Steam Turbines

In discussing the broad expediency of power distribution from central steam stations, it is not necessary to consider the relative merits of turbines of different types. The value of the product of such machines is so great in proportion to their cost that wide variations of efficiency cannot be tolerated, and it may be said that all large turbines are good as compared with other apparatus for obtaining power from fuel. In large turbine units, a variation of 10 per cent in efficiency might justify the scrapping of one machine and the purchase of another, unless the inferior machine could, as is usually the case, be used as a reserve or peak load unit.

The best steam turbine station equipments, operating under favorable conditions, can deliver a horse power hour in the form of electricity with an expenditure of one pound of coal, while four pounds are required to deliver a horse power hour to the drawbar of a good locomotive. The locomotive is further subject to many disadvantages, its fuel supply must be delivered and stored on a relatively small scale in many inconvenient places, and its efficiency is greatly affected by conditions of temperature. Its water supply is also a matter of much trouble and

expense. While the comparison of efficiency between the large power station and the smaller engine or turbine equipment used in small stations and isolated power plants is less striking than that with the locomotives, it is nevertheless highly unfavorable to the small plant, and this is fully demonstrated by the rapid growth in the use of central station power in industrial plants large and small. The important requirements for economical power production in turbine stations are: large and continuous demand, facilities for economical purchase, handling and storage of fuel, and an ample supply of condensing water.

Power delivered near centers of demand where load factor is high has a much higher value than that produced in remote places, that is, it pays to transmit power long distances for occasional or irregular demand, while for large and continuous demand it is profitable to produce it locally.

Our large rivers with their fertile valleys have naturally focused our centers of population and of transportation facilities. They afford the requisites for economical power production, and the lines of railways correspond generally to the natural arteries for its distribution. To accomplish ideal results in power production for general uses over large areas will require broad cooperation, and dependable financial conditions under such franchises as will give reasonable security against political attacks, and which will give scope for the many progressive individual activities which are gradually developing the electrical art and educating the public to its uses.

2. J. F. JOHNSON

Large Steam Turbines

The economy benefits resulting from the proposed consolidation and expansion of electric power production, distribution, and application in a portion of the New England and middle Atlantic section, properly organized and managed, and amply financed, would undoubtedly be very great. Problems involved would require the services of our greatest engineers of finance, organization, distribution, and production, but the writer can see no reason why these should not be satisfactorily and profitably solved.

The problem affecting the steam turbine designer is only a very small portion of the general problem of production. With an electric power generating station, as with a manufacturing establishment, constant output at as nearly as possible full normal capacity is the first requisite to high efficiency or its equivalent, low cost of production.

Studies of the load curves of the various districts served will, no doubt, be made to determine the probable load factor obtainable by the proposed consolidation and expansion.

The greatest amount of saving in cost of production of power is to be made by the discontinuance of the many small and medium sized generating stations, many of which contain apparatus which is either obsolete, incomplete, or uneconomically arranged, and replacing them with large capacity stations designed for maximum reliability and efficiency. This would include the development of available water powers to the maximum degree feasible, and the addition of such steam power stations as would be necessary. Against this saving would, of course, have to be charged the costs and losses incident to the increased distribution system required.

The design of the steam generating stations, such as would be required, should probably not differ materially from those being employed for our largest and most modern stations now building, and their efficiency would not differ materially from those now obtainable except as affected by the higher load factor under which they would operate.

Reliability would, of course, have to be the first aim of the designer, and this requisite would preclude the adoption of experimental apparatus or conditions widely removed from those now used and known to produce satisfactory results.

Generating stations of from 200,000 to 300,000 kw. capacity, employing generating units of from 50,000 to 75,000 kw. capacity, each operating on steam conditions of 300 lb. pressure, 200 deg. fahr. superheat, and 29 in. vacuum referred to a barometer of 30 in., would involve no difficulties of design, construction, nor operation, and from such stations a steam consumption rate of 10 lb. or less per kw-hr. and total station rate of less than $1\frac{1}{2}$ lb. of good quality coal per kw-hr. output should be obtained.

Steam turbines of the multi-cylinder type, similar to those now in use and under construction would possess advantages because of their reliability, efficiency, and flexibility, and also because of their adaptability to other operating conditions, should changes become advisable by reason of further experience or development. Only the high pressure element of a multi-cylinder unit would require alteration to meet such a change of conditions.

3. H. G. REIST

Large A-C. Generators

The following brief discussion has reference to generators needed in a proposed super-power zone extending through the southern part of New England and the southeastern part of New York and Pennsylvania to Washington, D. C. In this area there would naturally be a number of power houses located at points where condensing water was available and where coal could be delivered with the least haulage by rail. Probably most of these power houses would be located on tide-water; others, in the vicinity of the coal mines.

The size of the generating units for such a project will undoubtedly be determined largely by the output

required from individual power houses. Probably there would be at least five generating units in each installation, so that repairs and inspection of the units could be made without much reduction in output at any point. Any reduction in output would have to be supplied from neighboring power houses and the transmission of large masses of power should naturally be avoided to limit the line losses. Nor should there be an excessive number of machines, as this would increase the cost of attendance and installation. A second consideration in determining the size of the units is the economical maximum size of the steam turbine. This subject was discussed at length at a recent meeting of the A. I. E. E. and we may assume that three-phase generators can readily be built for the limiting sizes of the steam units suggested at that time. It seems probable that whatever frequency is selected for this system of distribution, turbines and generators can be supplied to meet the most desirable number of units to be placed in each installation. So many generators of from 30,000 to 50,000 kv-a. are at present in operation, giving satisfactory service, that there need be no hesitancy in considering generators as large as those now in use, or larger.

The potential of these generators should be within the limits of our experience, that is, not above 13,200 volts and preferably lower, if this does not cause inconvenience in the lines leading from the generators to the step-up transformers. The efficiency of large modern generating units is very high. The losses may be expected to be less than 2 per cent of the output of the machine, but even with these small losses, careful attention must be paid to the design of the machine to get satisfactory ventilation so as to keep all parts of the machine reasonably cool. While it is permissible to allow a high temperature on the rotating element, with normal maximum potential of 125 or 250 volts in the windings it is better to restrict the heating in the stationary element to a temperature which will not impair the materials used for insulating the windings. It is recognized that nearly all our flexible insulating materials, such as, paper, cloth, fibre and varnishes, deteriorate at a temperature slightly above 100 deg. cent., with greater or less rapidity. The well-known exception to this rule is mica, but an insulation of mica as applied in electrical machinery, consists of a multitude of thin flakes held together by shellac, or other varnishes which also seal the interstices between the flakes. The electrical resistance of all such varnishes decreases with increase in temperature. With some of these materials, the resistance decreases rapidly at temperatures as low as 75 to 80 deg. cent. Other varnishes, especially some that have been developed in recent years, retain their resistance at considerably higher temperatures. When the subject is considered from all standpoints, it seems undesirable to operate such important machinery at a higher temperature than is allowed by "Class A" insulation in the American Institute Rules. Nor is there much objection to insisting on low temperature on such large machines, since the increase in size and cost of cool machines is negligible as compared with those operating at higher temperatures. Moreover, the mechanical construction should be such as has been tested and found to be reliable. The machines should be designed to have minimum losses and an efficient system of ventilation.

Big generators are cooled by circulating a very large amount of air through the various ducts provided for this purpose in the machine. Any soot or dirt in the air, and the air always carries some of this material, is liable to be deposited on the surfaces of the ventilating ducts and on the exposed surfaces of the coils, thus greatly reducing the efficiency of these surfaces in transmitting the heat to the circulating air. To avoid this deterioration, the air is generally passed through air-cleaning apparatus which removes about 98 per cent of the dirt contents, but even with this cleaning, a considerable amount of dirt will accumulate. An improved method of cooling which has been adopted in a few cases and which has excited the interest of engineers in many other installations, is to enclose the air used in cooling the generator completely, and to re-circulate it, thus not taking in any new air. The circulating air may be cooled by the familiar spray system, but in many cases it is preferable to cool it by a system of radiators, similar to those used on automobiles, only they function to cool the air passing through, instead of cooling the water, as in a motor car. Under certain conditions, the water from the condensed steam may be used as a cooling medium in these radiators. This offers a method of returning part of the heat to the boilers, thus saving a small amount of heat which ordinarily is lost. In this way there is no opportunity for dirt to get into the system.

A closed system of ventilation offers some advantage in extinguishing internal fires which sometimes occur, since it will be possible to retain gases or vapors, which may be used in putting out the fire. It is difficult to do this with the ordinary system of ventilation, since the rapid circulation of the air, of which there is a continued new supply, blows gases out of the machine very rapidly even if enclosing dampers are provided.

On account of the great capacity of the lines in such a large system, there may be some advantage in the use of induction generators. Such machines cannot readily be built in as large sizes as synchronous generators, for the following reasons:

1st. Such machines, having smaller airgaps, are more difficult to ventilate than standard synchronous generators;

2nd. Magnetizing current must be supplied through the armature winding. Therefore, larger current is required in the windings which have to be insulated against the potential of the machine;

3rd. The rotor must be at least partly built of laminated iron, making it impossible to design as stiff a structure as otherwise, thus reducing the critical speed.

Roughly, the size of an induction generator would

probably be from 25 per cent to 30 per cent larger than a synchronous generator and the cost of the machine in proportion. Since the present limit in the design of steam turbine generator sets is due to the turbines and not to the generator, except possibly at 3600 rev. per min., I believe that it is possible to construct induction generators in sizes comparable with the most efficient operation of the turbine, that is, perhaps 20,000 to 25,000 kw. at 1800 revolutions, and 40,000 kw. at 1200 revolutions, for 60-cycle machines. We might assume that the same conditions hold in connection with 25-cycle generators. The efficiency of induction generators would probably be about 1 per cent lower than of synchronous machines.

In the territory to be supplied by the super-power system, power is at present being distributed at a number of frequencies, such as, 25, 40, 60, 62½. I will not attempt to explain the reason for these various frequencies, but no doubt all of them were, or seemed, justified when they were adopted. The present tendency is to standardize 60 cycles, rather than 25 cycles, since the latter cannot be used for lighting and higher frequency gives greater flexibility to the speed of industrial motors. Synchronous converters and motor-generators can more readily be operated from 60 cycles for transforming to direct current, than from 25 cycles, since there is greater choice in the number of poles of the motors. The use of 60 cycles will be a handicap on the transmission line, but probably the line will be sectionalized and very long transmission of power will be the exception, rather than the rule, so that it is possible that these inconveniences may be overcome. Since much machinery has to be replaced, and a large amount of new machinery added, and since the transmission conditions would be better at a frequency lower than 60 cycles, I think it is well to give consideration to the use of 50 cycles on such a project. This frequency is entirely satisfactory for lighting, for commercial motors of all sizes, and for almost all other work, and it would probably be found that ultimately its adoption would be a great advantage to this country commercially, since we should then have what is going to be the world frequency outside of the United States. It might be well to consider the adoption of this frequency now, rather than to let the matter drift and suffer the inconveniences of the continued use of a frequency different from the rest of the world, and ultimately to find it desirable to change our standard at much greater inconvenience and expense than if it were done now.

4. F. D. NEWBURY

Large A-C. Generators

I have given this subject, as presented in Mr. Murray's several letters and in his paper printed in the January A. I. E. E. Journal, careful consideration. I have not been able to give this matter the time it deserves, but trust the following notes will give my point of view, in regard to the generating end of this subject.

The generating element in the proposed Boston-Washington power supply system does not involve anything new or untried. The individual power stations need not, and probably would not, be any larger than stations now in operation, or under construction. Certainly, any probable station involved in carrying out this super-power development could be designed with steam and electric generating units of a size now available.

Suppose we assume a station of 300,000 kw. to 500,000 kw. total capacity. We have available single shaft generating units up to 40,000 kw., with generators of 50,000 kv-a. capacity. The preferred speed for such a unit would be 1200 rev. per min., 60 cycles. Eight to twelve such units would give the assumed total station capacity.

There has also been developed and built triple-shaft cross-compound units of 60,000 kw. Five to eight such units would constitute as large a station as has been suggested. This triple-shaft unit consists of three 20,000 kw. turbine cylinders and generators. There is one high pressure element at 1800 rev. per min. and two low pressure elements at 1200 rev. per min.

All of the generating units referred to are actually conservative in size, and by no means represent the largest units of the speeds in question that could be designed. Information concerning this latter point is given in the recent papers by Eskil Berg and J. L. Johnson, on Steam Turbines, and the writer on the subject of Turbo Generators.

As regards the general subject of the single source of power supply within the zone outlined, I believe that the scheme will have to be developed by building up local central stations. It would seem that the greater part of the gain in economy can be secured if all the power requirements of the given local territory, such as Boston or New York, or Philadelphia, or Baltimore, were supplied from local central station systems. The problem of connecting up such local systems in one super-power scheme and interchanging power in both directions from each local system presents a problem of considerable engineering difficulty, and questionable economic advantage in the present state of the art, and in the present state of central station development. There remains so much to be done in developing each local territory that it would seem wisest to carry this on before attempting linking up several local power systems.

5. W. B. POTTER

Heavy Traction Locomotives

The suggested system of interconnected economic power generation and distribution throughout the proposed super-power zone should adequately and advantageously provide for the electric operation of the

railways within this zone, as well as for the power required for industrial and other purposes. The electrification of these railways would not only insure a substantial reduction in the amount of coal otherwise consumed by the steam locomotives, but would also materially reduce the cost of maintaining the motive power units. Electrification would also provide a more reliable service for all classes of traffic and be a welcome improvement to the traveler as passenger trains would be less frequently late, especially during the winter. The colder the weather the greater is the reserve power of the electric locomotive, which is a much better characteristic than that of the steam locomotive whose power under similar conditions is correspondingly diminished.

There are numerous illustrations of electric operation, which are comparable to the service within the zone under consideration, as well as many other examples of railway electrification throughout the country and abroad, which afford conclusive evidence as to the successful operation of railways with electric power. In fact, a large number of railway electrifications are already embraced within the limits of the proposed zone, and while they do not represent a large proportion of the total mileage, their traffic statistics are available and can readily be studied as a basis for determining the demands of the whole area. A tabulation of these electrifications shows that in this area there are already 380 miles of electric route, embracing 1450 miles of single track and operating 230 electric locomotives and about 1000 motor cars for multiple unit suburban service. A table showing the data of the various roads embraced in this statement, is presented herewith.

TABLE I

Steam Railroad Electrification in the Super-Power Zone

Railroads	Date of electrification	Route Miles	Total mi. of track	No. of locos.	Motor Cars
Balt. & Ohio R. R.	1895	3.6	8.	9	0
L. I. R. R.	1905	88.63	218.	0	477
N. Y. C. & H. R. R. R.	1906	54.00	258.	73	221
W. J. & Seashore R. R.	1906	74.60	150.26	0	109
N. Y. N. H. & H. R. R.	1907	81.63	527.49	106	27
Penn. R. R. (New York)	1910	18.73	97.49	33	8
Boston & Maine R. R.	1911	7.97	21.50	7	0
N. Y. West & Boston	1912	18.23	54.41	1	40
Penn. R. R. (Phila.)	1915	30.5	116.3	0	115
		377.89	1451.45	229	997

In order to obtain a general picture of the railroad traffic which would be affected by the power supply of the super-power zone, we have made a study of the traffic conditions of the territory covered by the zone. In making this study, we have taken data from the Operating Reports of the United States Railroad Administration, extending over the months of 1919, for which comparable figures are available.

The reports of the Railroad Administration do not give separate traffic statistics of the various divisions of the roads embraced in their report, and there is necessarily some uncertainty in estimating the portion of each road and the traffic which would be embraced in the zone. We have tabulated the mileage of those divisions of each road which would presumably be included in the proposed super-power zone, thus determining the percentage of the total mileage of that road lying within the zone. This percentage, or ratio, we have applied to all other data of the road in order to determine the traffic within the zone. This factor, therefore, determines the number of locomotives, the amount of traffic which would be handled electrically instead of by steam, and the tonnage of coal which would be replaced by electric power. In view of these assumptions as to probable area of the super-power zone and the amount of included traffic, the estimate as given can only be an approximation.

As the detailed figures obtained from the Operating Reports do not apply to switching service, we have added 20 per cent to the mileage and tonnage to cover switching service, and as the power requirements per ton-mile for switching are approximately double those for main line service, we have added 40 per cent to cover the coal consumed in the switching.

On this basis we estimate that the railroad traffic in the region covered by the zone can be represented, approximately, by the following table:

TABLE II

Railroad Traffic in the Super-Power Zone (Passenger, Freight and Switching)

Miles of route	12,000
Miles of single track	30,000
Locomotives in service	8,100
Locomotive miles annually	185,000,000
Gross ton miles annually, including main line and switching movements of passenger trains, freight trains and locomotives	170,000,000,000
Tons of coal consume annually	21,000,000

Considering railway electrification broadly throughout the whole country and including only those lines which handle freight and passenger service with electric locomotives, we find there are about 700 electric locomotives operating over 5000 miles of route.

There have been some data published on the results of heavy electrification. The papers to which we would particularly refer are,—

Murray—*Electrification Analyzed and its Practical Application to Trunk Line Roads.* TRANS. A. I. E. E., Vol. XXX, 1911.

Cox—*Electrical Operation of the Butte, Anaconda & Pacific Rwy.* TRANS. A. I. E. E., Vol. XXXIII, Sept. 1914.

Beeuwkes—"Operating Results from the Electrification of the Trunk Line of the C. M. & St. P. Ry." New York Railroad Club—March 16, 1917.

From data available, it would appear that the ton-

miles moved by 6½ pounds of coal in a steam locomotive is approximately equal to that which can be moved by one kilowatt-hour delivered from the power station. Applying this ratio to the last item in Table No. 2, the electric energy required to handle the traffic now handled by the 21,000,000 tons of coal to steam locomotives would be approximately 6,500,000,000 kw-hr.

If we assume 40 watt-hours per ton-mile at the power station, which checks fairly with the records of a mixed service of main line and switching, the total energy for moving the assumed traffic of 170,000,000,000 ton-miles, would be approximately 6,800,000,000 kw-hr.

The actual requirements would, however, be something less. It has been estimated that of all the tonnage moving over the railroad, approximately 12 per cent is taken up with the movement of railroad coal to points of distribution, including a second movement of the same coal in the locomotive tenders. Making an allowance for railroad coal that would still be required, a reduction of 10 per cent would seem a fair estimate. This would correspondingly reduce the yearly power requirements to about 6,000,000,000 kw-hr.

On the basis of probable load factor, this would call for about 1,250,000-kw. of power station equipment.

Conclusions

The conclusions to which this discussion points may be summarized as follows:

1. Of the whole mileage included in the zone, a not very large proportion has been electrified, but main line electrifications now in operation are of sufficient extent and carry tonnage of a character to present data which can be fairly applied to the traffic of the whole district.
2. The traffic within the zone now handled by steam locomotives, if handled electrically, would require an average output of less than 750,000 kw. and if produced entirely by coal-burning electric power stations, would reduce the coal requirement for transportation purposes from 21 million tons to 7 million tons annually.
3. As a certain proportion of the electric power will be produced from hydraulic power stations, this coal requirement will be reduced in proportion as advantage is taken of hydraulic operation.
4. The reduction in cost of maintaining the motive power units would be a large amount which estimated from the locomotive mileage would be in the order of $15,000,000 or more, annually.

6. PHILIP TORCHIO

Role of Water Power and Coal in Super-power Systems

A review of the resources and consumption of coal and the availability of potential water powers in the United States shows that:

1. The *Western States* (Mountain and Pacific) have resources in both coal and water powers to meet indefinitely all their heat and power requirements from either source of supply; the potential water powers alone being large enough to supply over six times all heat and power requirements of 1915.
2. The *other states*, with corresponding heat and power requirements 40 times greater than the Western States, have actually smaller resources in coal and potential water powers, the latter capable of supplying only 8 per cent of their total heat and power requirements. It follows that these states must indefinitely, so far as present human knowledge can foresee, depend upon the use of coal to supply the great bulk of these needs.
3. These states, comparatively so deficient in water powers, consumed in 1915, 528,000,000 tons of coal, about one-half for generating power and one-half for generating heat. They obtained an average efficiency from coal of 5 per cent for the power and 50 per cent for the heat. With present methods of generating power in large, modern central stations the efficiency from coal has been raised to 19 per cent. If all the power had been so generated, the coal saving would have amounted to 185,000,000 tons and the railroads relieved of two thirds of this kind of freight.
4. As the investment cost of a steam plant is only about one-third or one-quarter that of a waterpower development with its transmission connections and steam reserve, and as all other items of investment for the electrification of industrial plants would be the same with power generated either by steam or waterfalls, it follows that every dollar invested in modern steam plants will make available several times more power for the industries than a dollar invested in hydroelectric plants.
5. The offset for the greater overhead charges of hydroelectric power is the saving in coal. The value of this saving will be more or less, according to whether the power is used more or fewer hours every day of the year, and according to the unit price of coal.

Under American conditions, the value of coal saving derived from the use of water power is usually smaller than the difference in overhead charges between steam plants and hydro-plants, except in cases where the power is used continuously every hour of the year, or where the development is connected to a large steam power system which will absorb the entire possible output.

6. With certain industries like electro-chemical processes and the refining of metals, using immense amounts of power continuously, the net cost of hydroelectric power may be considerably less than steam power. There is a great advantage of the whole Nation of devoting as much as possible of the economical water powers, particularly those which are continuous or nearly so and those without regulatory daily storage to intensify the development of these industries which can prosper and render their full benefit to the Nation only under conditions of mass production and most favorable cost of power.
7. In considering the technical and practical fea-

TABLE I—REVIEW OF SUPPLY AND CONSUMPTION OF COAL BY CLASSES AND TERRITORIES, AND

	H.P.	H.P.hrs. (Millions)	Yearly consumption tons		
Primary Power					
Steam railroads	50,000,000	60,000	128,000,000		
Central Station & Electric Railways			18,000,000		
Steam	8,000,000	16,000	....		
Hydraulic	4,000,000	17,000			
Manufacturers & Isolated Plants					
Steam { Electrical—44 per cent; Mechanical—56 per cent }	25,250,000	46,800	87,750,000		
Hydraulic	4,000,000	12,000			
Mines & Quarries	6,000,000	9,600	18,000,000		
Steam & Naval Vessels	5,000,000	10,000	10,000,000		
Miscellaneous Mills & Irrigation	1,750,000	2,800	5,250,000		
Total Power—Steam	96,000,000	145,200	267,000,000	Western states	7,000,000
				Other states	260,000,000
Hydro	8,000,000	29,000	....		
Total	104,000,000	174,200	267,000,000	Western States	7,000,000
				Other states	260,000,000
Heating					
Industrial steam	....	....	90,000,000		
Domestic & small steam	....	....	118,000,000		
Coke—Beehive	....	....	42,000,000		
" By-product	....	....	20,000,000		
Coal Gas	....	....	5,000,000		
Total	....	....	275,000,000	Western states	7,000,000
				Other states	268,000,000
Grand Total—Steam	....	....	542,000,000	Western states	14,000,000
				Other states	528,000,000
Hydro	....	....			
Total	....	....	542,000,000	Western states	14,000,000
				Other states	528,000,000
Potential Water Power		100 per cent load factor Assumed			
Average Continuous 90 Per Cent Efficency					
Western states	33,422,000	293,000	....		
All other states	13,458,000	118,000	....		
Total—United States—Average	46,880,000	411,000	....		
" " " —Minimum	32,082,000	....			
" " " —Maximum	61,678,000	....			

THE RELATION WHICH THE POTENTIAL WATER POWERS BEAR TO THE AMOUNT OF COAL USED IN THE UNITED STATES

Total energy in coal est. 12,000 b.t.u. per lb. (In millions b.t.u.)		Total energy utilized (In millions b.t.u.)		Per cent efficiency	Possible efficiency with modern improvements applied	Difference —Tons of Coal— which could be saved if its value balances carrying charges of extra investment required
					Per cent	
3,070,000,000		153,000,000		4.99	18.98	94,000,000
432,000,000		40,800,000				
....		43,300,000		9.45	18.98	9,000,000
				....	....	....
2,105,000,000		119,200,000		5.66	18.98	61,700,000
....		30,600,000		....	....	....
432,000,000		24,450,000		5.66	18.98	12,600,000
240,000,000		25,470,000		10.60	18.98	4,400,000
126,000,000		6,500,000		5.15	18.98	3,800,000
6,405,000,000		369,420,000	Western states 9,420,000 Other states 360,000,000	5.75	18.98	185,500,000
....		73,900,000	Western states 22,900,000 Other states 51,000,000	....	....	....
6,405,000,000		443,320,000	Western states 32,320,000 Other states 411,000,000	....	18.98	185,500,000
2,160,000,000		1,297,000,000		60	70	12,800,000
2,840,000,000		995,000,000		35	60	49,000,000
1,010,000,000		657,000,000		65	85 + By-products	10,000,000 + By-products
480,000,000		408,000,000		85	85	0
120,000,000		108,000,000		85	85 + By-products	0 + By-products
6,610,000,000		3,465,000,000	Western states 89,300,000 Other states 3,375,700,000	52.5		71,800,000 + By-products
13,015,000,000	Western states 335,000,000 Other states 12,680,000,000	3,834,420,000	Western states 98,720,000 Other states 3,735,700,000		....	257,300,000 + By-products
		73,900,000	Western States 22,900,000 Other states 51,000,000		....	
13,105,000,000	Western states 335,000,000 Other states 12,680,000,000	3,908,320,000	Western states 121,620,000 Other States 3,786,700,000		....	
					....	
		746,000,000				
		300,000,000				
		1,046,000,000				

tures of the special problem affecting all the states (exclusive of the Western States) having insufficient potential water power to meet their present and larger future demands, emphasis should be laid on the importance of concentrating the national efforts to secure the largest possible coal savings in co-ordinating modern methods of power generation by steam. Heavy losses would follow a policy of handicapping these developments by any method of water power development which would involve diverting from them the few but most economical large commercial loads, and duplication of plant and substitution of water power, and relegating the steam plants to supply the larger in aggregate but less desirable loads of small commercial and domestic services, with poor utilization of the apparatus on account of low average use of power each day during the year.

Where water powers are used as auxiliaries to general power distribution systems, the most economical conditions for both steam and hydroelectric generation can be fulfilled only where a relatively small proportion of the installed generating capacity is hydroelectric.

8. These conclusions would not apply to the Mountain and Pacific States, where the potential water powers are enormous and of cheaper development and can be depended upon to furnish all local power requirements to a very distant future.

The Utilization of Water Powers as a Measure of Fuel Conservation

The harassing experiences of coal famines have brought forth repeatedly pressure that immediate efforts be directed to the development of the potential water powers of the country. While from the general standpoint of conserving the national coal resources the proposition deserves the most favorable consideration, it is questionable whether quicker and greater results could not be obtained by concentrating the effort upon improving and changing wasteful methods of utilizing coal.

This we shall discuss under two main headings, one surveying the value of "Potential Water Powers as Sources of Saving Fuel;" the other reviewing the "Technical and Practical Features Attending the Utilization of Water Powers;" so that with the aid of the first survey we may arrive at a clear understanding of the logical lines of development and application of potential water powers for the best interests of the Nation.

1. *Potential Water Powers as Sources of Saving Coal.*

In order to appreciate the situation with respect to utilization of waterpower, it may not be amiss to give a bird's-eye view of the supply and consumption of coal by classes and territories and the relation which the potential water powers bear to the amount of coal used in the United States.

In Table I are given, in detail, for the year 1915, the amount of coal consumed under the two main classifications of coal used for:

Primary power	267,000,000	tons:
Heating	275,000,000	"
Total	542,000,000	"

On the basis of estimates made by the United States Geological Survey, and assuming that only about 60 per cent of the total supply will be recoverable, we find that the present supply of coal in the United States, exclusive of Alaska, if consumed at the rate of the 1915 yearly consumption, will last *four thousand years.* The supply in the Western States amounts to about two-thirds of the total of the United States, exclusive of Alaska. The supply in the remaining states, if consumed at the 1915 rate of about 500,000,000 tons per year, would last *one thousand years.* The greatest shortage is in the supply of anthracite, which, if consumed by the anthracite using states at the rate for 1915, would last only *one hundred years.* In any case, therefore, the saving of coal during one generation is not of vital importance.

This disposes of the immediate urgency of considering the conservation of coal per se, at least for the time being, while more pressing subjects demand attention. The vital importance in conserving railroad facilities, need not be considered provided similar coal savings are made by one means or another.

The next point to visualize is the relation between the national coal requirements and the extent to which they could be supplied by the utilization of water powers in place of coal. We find, using Table I, that the 542,000,000 tons of coal produce a total energy figured in terms of million British thermal units of 3,908,320,000 units,

121,620,000 in the Western States, and
3,786,700,000 in all other states.

If all the water powers of the country were utilized they could replace 1,046,000,000 or 27 per cent of the above stated units, of which are available
746,000,000 in the Western States
= 614 per cent of total energy used, and
300,000,000 in all other states
= 8 per cent of total energy used,

The water powers already developed represent 73,900,000 units of which
22,900,000 in the Western States
= 19 per cent of total energy used, and
51,000,000 in all other states
= 1.4 per cent of total energy used,

while the Western States possess large waterpower resources to furnish several times their total power and heat requirements. All other states, are inadequately supplied with water powers. Considering the present commercial limitations of distances for electric power transmission, they could not receive assistance from the excess water powers of the Western States. Their

own water powers, even if fully developed, could not replace more than 8 per cent of the energy required. As about one-sixth of their waterpower is already utilized, the *balance would give only about 6 per cent of their power and heat requirements.* From this arises the necessity of an enlightened national policy encouraging and protecting the efforts of such industries as could be instrumental in realizing savings of coal with all other incidental economies.

While the resources of these states are very great, the coal consumption has been steadily increasing from year to year at the rate of about 10 per cent, and if this increase continues, even the present immense reserve would be exhausted in a small fraction of the 1000 years, without large water power resources to fall back upon in a future not distant as measured by the life of nations.

Coal is used to produce either *primary power* or *heating.*

Referring to Table I we find that all of the coal used in the United Stated approximately *one-half* is for producing power and *one-half* for producing heat.

We find further that in producing power only about 5 per cent of the total energy in the coal is utilized, while in producing heat about 50 per cent is utilized. (These figures do not take into account additional losses met in the transmission and utilization of power or heat, as the case may be).

It is evident from these figures showing the low economy of coal for producing primary power that in this field the utilization of water powers would produce the greatest savings in coal.

The economic value of water powers in conserving coal resources is therefore manifest, but *one of the questions to be considered* is whether at the present time quicker and greater results could not in most instances be obtained by the alternative proposition of securing equivalent or even greater economies through improvements in present methods of generating power or heat from coal.

Analyzing the classified means of power production by services, we find that central stations and electric railways realize the highest efficiency from coal, while all other classes of steam power producers obtain from coal about one-half as much as the central stations. Furthermore, with modern equipment the central stations could obtain nearly twice as much work per pound of coal as the present average from their existing equipments. By supplying with electric power all railroads and industries using steam power this could be done, if generated by modern equipment in central stations, for about one-third the present consumption of coal. The total saving would represent 185,500,000 tons of coal, and the railroads would be relieved of two-thirds of this kind of freight.

To realize these coal economies, it would be necessary to make investments for new steam or hydraulic generating equipment to replace the discarded existing steam locomotives on railroads and steam engines in private plants. In all other cases, with the exception of 11,000,000 horse power in existing private plants which already generate electricity for their operation, it would be necessary to introduce a universal electrification of services, substituting electric motors for mechanical drive in plants and electric locomotives on railroads.

In ultimate analysis, each individual case would have to be studied on its economic merits, but, aside from many technical advantages which the electric operation presents over the operation by steam, which advantages may be of greater importance than the mere saving of coal, in general, for a rough approximation, one may assume that a proposition for electrifying an existing steam-driven plant or a steam railroad will be economically advantageous or not according to whether or not the *fuel saved* will *balance the carrying charges of the cost of electrification.* It will appear, therefore, that in general the unit price of fuel will be the fundamental determining factor of the solution. As an illustration, it has been found that in Italy, where the coal price before the war was ten dollars per ton delivered to the locomotive, the saving from electrification of two-track railroads, with electricity at 1 cent per kw-hr., balanced the extra carrying charges of electrification when the roads consumed 700 tons of coal per mile—equivalent to $7000 cost of coal per mile of road.

I repeat that there are many other considerations to take into account in any specific problem, but the broad fundamental principle holds that the unit price of fuel will determine the net economy of transformation from one power service to another of superior fuel economy. While, therefore, by electrification of railroads and manufacturing plants and substitution of modern efficient apparatus in central stations, we could today, reduce the yearly coal consumption for primary power from 267,000,000 tons to 82,000,000—*a saving of* 185,000,000 *tons*—it is doubtful whether the coal saving would balance the carrying charges for the extra investment required.

In different cases the economic advantages would often times be lacking. This would apply particularly to many railroads, but, on the other hand, the centralization of supply for manufacturers and isolated plants, mines, quarries, etc., would in the majority of cases come within economic limits, and the major part of the indicated possible savings for these services of 74,300,000 tons could be realized in a relatively short time. To accomplish this most economically the central station power undertakings already covering the country with a network of transmitting lines, distributing stations and service lines

1. Should further centralize their production and increase the interconnections between their own and neighboring generating plants, and possibly locate new plants in the coal fields or at by-product gas and coke works; and

2. Should install modern generating apparatus to obtain the highest coal efficiency, and operate this new apparatus more or less continuously, reserving the existing less economical equipment for operation during occasional short periods of high demand for power, such as the evening hours of the winter months. In this manner the added modern equipment would not only serve to carry the new load of the industries transferred to central station service, but would also make a *large saving of coal for the existing load of the central stations.*

It is necessary that we fully realize the importance of this double saving from the addition of modern generating apparatus to existing steam central stations and also the fact that if hydraulic power be so utilized as to appropriate the most economical portion of the steam central station load, the operating costs of the remaining load on these stations, which will usually be required to supplement the hydraulic power, would increase perhaps more than the saving due to the lower cost of the hydraulic power. In addition, the new apparatus for a steam station could be located nearer to the customers who are to use the power, thereby saving the cost and losses of long transmission lines, and the safety of operation and reliability of the electric service would be incomparably greater under all conditions of weather or season or possibility of inimical interference with the lines.

In the foregoing we established the facts that:

All potential water powers are insufficient to provide the total heat and power requirements of the Nation;

The shortage is particularly striking in the case of the states east of the Mountain and Pacific States, hence

The railroads and industries of these Eastern States must always depend largely for their power upon coal;

If, in these states, steam central stations are confined mainly to supplementing hydraulic power from extensive hydro-electric systems, their power costs would increase, offsetting the savings from hydraulic power;

If, on the contrary, central station systems, unified on a large scale, a scale commensurate with that which would prevail in the case of hydroelectric systems, were developed with modern apparatus and correlated with new plants at coal fields, and by-product gas and coke works, etc., the savings in coal would in a few years fully equal the savings from the total potential water powers in the states east of the Mountain and Pacific States. Incidentally, these savings could be realized with a considerably smaller outlay of capital and within a shorter time than that required for the hydraulic development. Also, this program would avoid duplication of plants and conserve an important industry, already splendidly organized with plants and trained men, all confirmed in the enthusiastic faith that their work is the most material and influential factor in the upbuilding of the efficiency of the Nation.

In this respect, after all is said and done, one must admit that the men who are accomplishing the most in saving coal are the central station companies with their power engineers and the manufacturing companies with their motor salesmen, who are achieving the real results by substituting the wasteful small plants operating at 5 and 10 lb. of coal per horse power-hour with the central station supply operating at a coal economy to save over two-thirds of the coal for the same service. It may not be amiss to point out that the merits of waterpower or steam power are of only relative importance to a public utility operating under governmental regulation. Once the prices of service are regulated upon the basis of a reasonable return on investment values, it will be found that the relative savings from hydraulic power over steam power are of very small order as affecting the total cost of service to a customer. These small differences, with a unified system of steam-power generation as suggested, would entirely disappear for practically all domestic and manufacturing classes of service. The only possible exception would be for those rare instances where the customer makes use of a constant power almost continuously throughout the year.

This leads us to the study of the relative value of waterpower and coal power according to conditions of use and applications. We shall find, for instance, that for certain products which the Nation needs the producer must make use of cheap, continuous power, as these necessities could not be commercially obtained in competition with the same products obtained by the use of coal or from importation from other countries, except by power at an extremely low cost. These products, necessary to the Nation, consume in bulk enormous amounts of energy continuously throughout the year, and to these necessities it is obvious that hydraulic power could be applied at greater advantage than to almost any other application which does not make a similar large and continuous use of the available waterpower. These technical and practical points are covered in the following second part of this presentation.

II *Technical and Practical Features Attending the Utilization of Water Powers*

In normal times the exploitation of a water power is justifiable only when the expected economic saving equals or exceeds the results that could be obtained from steam power. The saving must also be predicated upon the existence of an assured market for the sale of the hydraulic power developed. In a few instances, hydraulic power has been secured as incidental to improvements in navigable rivers. It is impossible to generalize and give the value resulting from such double utilization, but it may be said that none of these improvements has been economically justifiable purely from the value of the hydroelectric power developed.

In general, the study of a water power development one must consider, besides the costs of the development,

The amount of water flow and its variation at different seasons, and

The maximum possible seasonal and daily utilization of the water powers by the industries to be served.

With the exception of a few rivers, like those fed from the Great Lakes, the water flow and consequently the power available for most of the potential water powers in the United States east of the Western States is very variable and without facilities for building in the mountain regions suitable reservoirs to impound the water

for the low periods. This is practicable only in situations like those existing in the West. On this account, it has been found necessary to install in conjunction with water powers, large auxiliary steam plants to supplement the deficiency of the water power at times of low water flow, except in instances where water powers are used as auxiliaries to steam systems of relatively large capacity.

The second point under consideration, that of daily utilization of the power by the industries served, is very important and is often overlooked by men not familiar with the operation of power plants. Only certain special industries, like electrochemical industries producing aluminum, carborundum, special steels, caustic soda, nitrate, calcium carbide, etc., can use available power continuously every hour of the day and every day of the year. The average power user, on the contrary, utilizes the maximum power for, say, eight hours a day only, and more or less irregularly even for that period, with no use on Sundays, holidays, etc. This characteristic of individual users makes the utilization of the maximum available power very low. By combining a great number of users, all supplied from one power plant, the conditions are ameliorated in respect to the utilization of the maximum power demand upon the central plant, as the resultant maximum demand is considerably less than the sum of the individual demands of every user. This results from the fact that all users do not reach their maximum power demand at the same time. But, notwithstanding this averaging of individual demands upon the central plant, the net utilization of the resultant maximum demand is still about eight hours a day or 2920 hours out of the possible 8760 hours in a year. In the case of water power plants without regulatory daily storage: the unused power between 2920 and 8760 hours in the year is entirely wasted.

Without further emphasizing this point of the poor utilization of the maximum power in communities, it appears that *where continuous water power is available*, the greatest usefulness is derived by applying it first to special industries and processes which require large amounts of electric power and can be operated continuously, or nearly 8760 hours each year, so that the waste through unused power is reduced to a minimum. If that is not possible, then the best means of utilizing the water power to the greatest advantage is to have it exploited by large power undertakings which can either so arrange their operations that they can utilize all the water power for carrying that portion of their load which is nearly constant throughout the year, leaving the heavy season peak loads to be supplied by their reserve steam stations, or can otherwise distribute the electric power over large territories, including cities, mining fields, agricultural sections requiring electric pumping for irrigation and other uses, so that the resultant utilization of the water power distributed over different places and periods of day or season is high, and the waste of unused available waterpower is reduced. This method of exploitation is economically feasible only where the price of coal is relatively high.

In the case of water powers with variable flow, presenting large variations between minimum and maximum available water power, the necessity for extensive operation of auxiliary steam plants greatly reduces the economic value of the hydro development as an independent source of power, a condition which exists with most potential water powers of rivers east of the Pacific States, where impounding of water is usually impracticable. Economic utilization of such water powers is frequently contingent upon their use in connection with steam power systems so large that the water power is a relatively small proportion of the total.

The economic value of a potential water power is calculable by comparing the investment and operating costs of the water development, plus the steam plant reserve when required, with the cost of an equivalent steam plant or plants. If the power is not to be utilized *in situ* and must be transmitted over long-distance transmission lines, the cost of these lines and the cost of their maintenance and operation must be added to the cost of water power.

To visualize the relative values of water powers under different conditions of water flow and utilization of power, we may make a few comparisons to approximately cover conditions existing in different localities. As costs figures for present prices are lacking I have used pre war prices.

To arrive at a basis for comparing costs, we have reviewed several existing hydroelectric developments and found that the costs per *kilowatt maximum* of power development were as follows:

One case—continuous power	= $167
One case—	= $198
One case—non-continuous power	= $188
One case—	= $238
One case—	= $222

The costs of these developments would be materially higher under present prices of labor and materials, but I shall neglect this feature and assume a cost of $180 per kw. maximum—a figure smaller than the average of the above five costs—and also neglect the extra cost for transmission lines where required. We shall also assume the low rate of 8⅓ per cent for interest, taxes and up-keep.

On the other hand, for the cost of steam plants, I shall assume $60 per kw. maximum—as the corresponding cost before the war—and the rate of 11 per cent for interest, taxes and up-keep.

The estimates for six illustrations are based in each case on the development of a 100,000-kw. plant. In the several cases the plant investments were:

Hydro without steam auxiliary.......	$18,000,000
Hydro with 50 per cent steam auxiliary	21,000,000

Hydro with 100 per cent steam auxiliary	24,000,000
All steam	6,000,000

These figures clearly illustrate the point that for the same amount of power the hydroelectric development requires several times the capital outlay of an equivalent steam plant.

From the detailed estimates of power costs I have abstracted the results in the following tables of comparison.

Before proceeding with the presentation of these comparisons, it may perhaps be well to caution the reader that the figures apply to the *increment costs* of securing power from new plants under the conditions given in the assumptions, and would not apply, for instance, to the cost of power from the average steam station operating apparatus considerably more expensive and less efficient than large turbo units of modern design.

It may also not be amiss to state here that the steam central station industry has made almost revolutionary progress in raising the efficiency to a maximum of about 19 per cent of the energy in coal, while older plant and the average isolated plant of today utilize less than 6 per cent. It is also reasonable to expect that, with time, still further progress will be made.

On the other hand, in the case of water powers, hydraulic plants have started with, say, 80 per cent recovery of the potential energy, and efficiencies of even 90 per cent have been reached so that no material progress may be expected in increasing the efficiency of hydraulic plants.

As a corollary to these considerations, it follows that with the free play of economic laws in industry, everyone must recognize the latent weakness of extensive water power development, except under the most favorable conditions of cost of development, marketability of product and liberal terms of water grant.

The following tables give comparisons of the *relative values* of hydroelectric and steam power for a number of specific conditions of service which cover all possible ranges of conditions that may exist for different situations of power production from very large plants equipped with modern apparatus.

I again note that the costs given are only theoretical relative increment costs based on pre-war prices of plant installation and operating labor. Actual costs were higher before the war and would be considerably higher at present both for hydroelectric as for steam power, but relatively higher for hydroelectric on account of greater investment charges.

I. WATER POWER CONTINUOUS—33⅓ PER CENT

Average Yearly Use of Kw. Maximum demand = 2920 Hours—Auxiliary Steam Plant 50 Per Cent of Capacity of Hydro Plant.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydroelectric	0.564 cent	0.564 cent	0.564 cent	0.564 cent
Hydro with 50 per cent steam	0.701	0.711	0.731	0.751
All steam	0.393	0.460	0.593	0.727

II. WATER POWER CONTINUOUS—66⅔ PER CENT

Average Yearly Use of Kw. Maximum Demand—5840 Hours—Auxiliary Steam Plant 50 Per Cent of Capacity of Hydro Plant. Similar estimates Have Been Made, from Which We Abstract the Results Comparing the Yearly Unit Costs and Cents Per Kilowatt Hour for the Different Sources of Power.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydro-electric	0.297 cent	0.297 cent	0.297 cent	0.297 cent
Hydro with 50 per cent steam	0.367	0.372	0.382	0.392
All steam	0.250	0.316	0.450	0.584

III. WATER POWER CONTINUOUS—91 PER CENT

Average Yearly Use of Kw. Maximum Demand = 8000 Hours. In this Case, as the Power is Practically Used Continuously, We Assume that, when Transmitted to Long Distances, it Will Require a 100 Per Cent Reserve Steam Station—Instead of the 50 Per Cent Assumed in the Two Previous Cases.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydro-electric	0.218 cent	0.218 cent	0.218 cent	0.218 cent
Hydro with 100 per cent steam	0.298	0.302	0.322	0.329
All steam	0.199	0.265	0.398	0.530

In the case of water power with variable flow, a condition prevailing on almost all rivers except those fed from the Great Lakes, we find that it is necessary to install a 100 per cent steam plant auxiliary for carrying the deficiency of low water flow and as a reserve against interruptions of transmission lines if the water power is utilized at considerable distance from the power plant. The amount of energy output require from the auxiliary steam station depends upon the load factor of the system and the period of drought on the hydro plant. For average conditions we obtain the following comparative results for similar conditions of service as figured in the case of *a constant water flow*.

IV. WATER POWER VARIABLE FLOW—33⅓ PER CENT

Average Yearly Use of Kw. Maximum Demand = 2920 Hours (2190 W.P —730 Steam)—100 Per Cent Reserve Steam Station.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydro with 100 per cent steam	0.825 cent	0.841 cent	0.876 cent	0 910 cent
All steam	0.393	0.460	0.594	0.726

V.—WATER POWER VARIABLE FLOW—66⅔ PER CENT.

Average Yearly Use of Kw. Maximum Demand = 5840 Hours (4380 W. P.—1460 Steam)—100 Per Cent Reserve Steam Station.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydro with 100 per cent steam	0.448 cent	0.465 cent	0.499 cent	0.532 cent
All steam	0.250	0.317	0.450	0.585

VI—WATER POWER VARIABLE FLOW—91

Average Yearly Use of Kw. Maximum Demand = 8000 Hours (6000 W. P. —2000 Steam)—100 Per Cent Reserve Steam Station.

	Cents per kw-hr. for coal at			
	$1 per ton	$2 per ton	$4 per ton	$6 per ton
Hydro with 100 per cent steam	0.341 cent	0.356 cent	0.386 cent	0.416 cent
All steam	0.199	0.265	0.399	0.530

Under present prices these estimated costs would be larger. This would influence especially the overhead charges for plants, which would make the relative increases larger for hydroelectric than for steam power. It appears from these comparisons that hydroelectric power offers material advantages only when it is continuous and is so used, but that, on the other hand, the cost of steam power is less than that of hydroelectric power for ordinary conditions of service, load factors and price of coal. For such conditions it may also be noted that even relatively large differences in unit cost are of a trifling amount in comparison with the total cost of service including all other items, common both to steam as well as to hydroelectric power, covering costs of transmission, distribution, metering, billing, etc.

Recognizing these economic conditions, it becomes evident that in shaping the policies of utilization of potential water powers to the best end of preserving investment and conserving fuel resources, hydroelectric developments yielding relatively large amounts of continuous power should be co-ordinated primarily to supply energy for the production of products which require large amounts of continuous power such as can best be generated from water powers. Following this policy, it is conceivable to see large centers of electrochemical industries developed in a not distant future to produce nitrates for chemicals, munitions and agricultural fertilizers, caustic soda, electrolytic copper, electrolytic zinc, aluminum, calcium carbide, carborundum, graphite, etc. As for other applications, while today it may appear visionary to state that eventually no steel will be produced without passing through the electrical refining process, some steelmen are firmly convinced that electrical steel will ultimately become standard, because of the saving that all users of such steel will be able to make in reduction of material owing to its great elastic limit and its uniformity.

Some of these industries are in their infancy; others are now either consuming great quantities of coal or contending against great odds in their development because of shortage in cheap electric power within commercial distance of the raw products.

By concentrating waterpower developments into these intensified fields of electrochemical and refining products, there would result the attendant economies of mass production which are an absolute necessity to enable any American industry to flourish or meet foreign competition with its cheaper labor. If, for instance, the utilization of the major part of the Niagara Falls power could be arranged for between the United States and Canadian Governments, it would not be a great stretch of imagination to forsee that center become the Pittsburgh of electrochemistry and electro metallurgy with railroads and waterways reaching out to the most inland points and to the oceans.

Developments on rivers with irregular flow can in general only be used with full economy when employed as auxiliaries to or in connection with steam power systems of relatively much larger capacities.

In the mountain and Pacific States, where the potential water powers are enormous, the development of these resources, to save the wasteful use of fuel oil, should be fostered on the widest possible scale.

7. PERCY H. THOMAS

The Super-Power Plant

The following discussion is intended to cover the chief factors underlying the economy and operative feasibility of the proposed scheme for interconnecting the electric power systems of the district of the country lying along the north Atlantic seaboard and putting them in reach of the cheapest sources of steam and water power. With the interconnection is associated the electrification of the principal railways. The existing power companies in the district and the railroads now electrified or which it is proposed to electrify constitute the principal power consumers and distributors and must form the nucleus of the system.

The most fundamental object and the most important advantages of the project from the community's point of view, are the conservation of coal and the relief of the railroads from the burden of hauling coal for their own use and for power supply, which coal haulage constitutes more than one-third of the total traffic. Other advantages are mutual support and interchange of power among power companies, more favorable diversity factor and cheaper generation of power.

To conserve fuel most effectively requires both the development of as much water power as may be economically justified and the burning of coal in the most economical manner, as well as the use of low grades of coal. To relieve the railroads of the burden of freight, requires the burning of coal as near the mines as feasible. Furthermore, economical generation of steam power requires use of large power houses. To meet all these conditions requires long transmission and a very great premium is thus put on low priced and economical transmission lines. In fact, operative practicability and low cost of transmission are the essential features of this project. This means the simplest practicable layout and the greatest possible power capacity.

The system shown in outline in Fig. 1 is suggested as one solution of this problem and as a suitable basis for discussion.

This system consists of a main 250,000-volt line connection Washington or Baltimore with Boston, via Wilmington, Philadelphia, Newark, New York, New Haven and Providence. This line is fed from a group of large stations at the nearest soft coal fields—perhaps on the upper branches of the Susquehanna, but in any case where condensing water can be obtained and from a second group at the hard coal fields, probably supplemented by the Susquehanna and Delaware River water powers. Each group of such powers would feed through a tap transmission line. If a large plant or plants on the St. Lawrence River should turn out to be feasible, another tap line could be run to connect with the main line probably where this line crosses the Hudson River. The length of this line would be about 250 miles, this distance being taken to a junction point with the main line. The total distance to New York probably will be 300 miles or somewhat over.

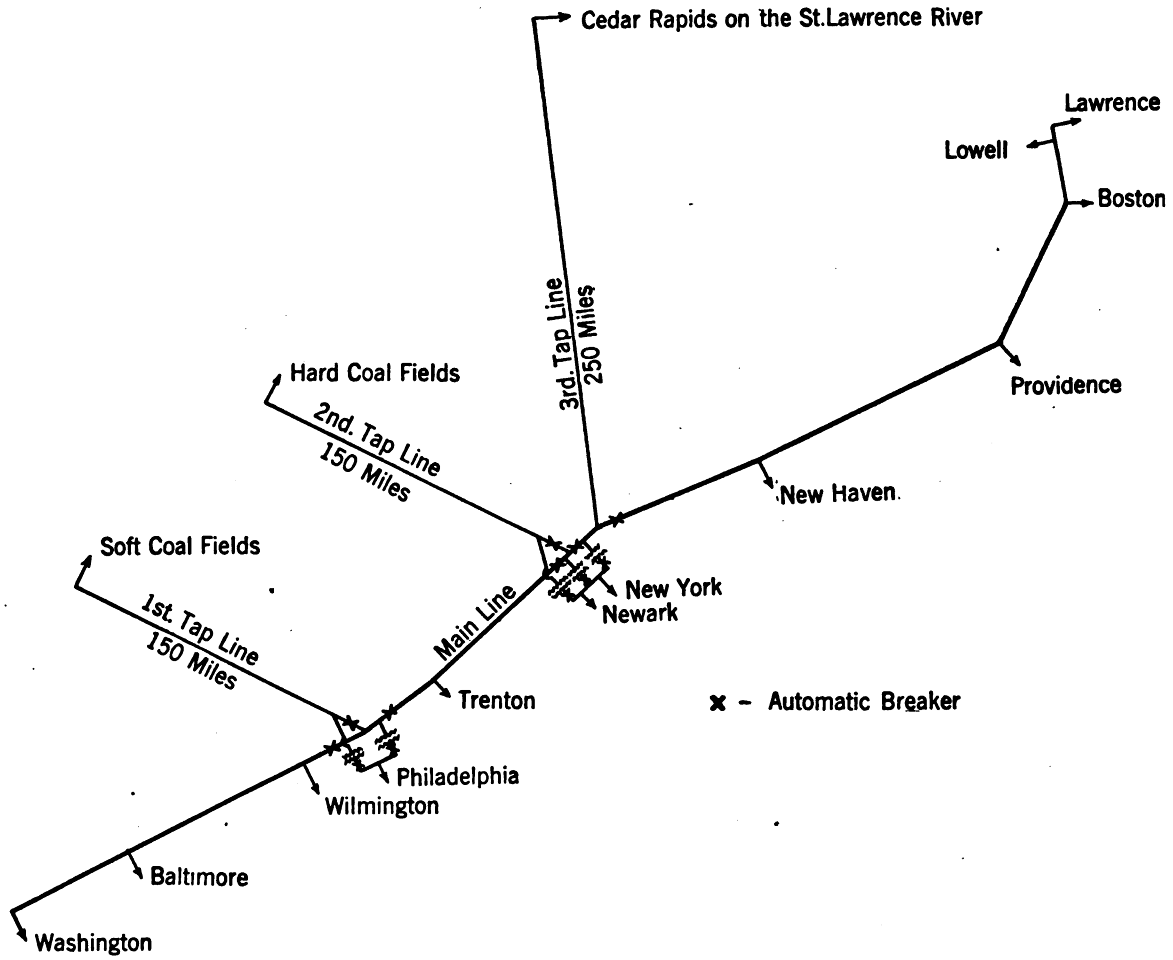

Fig. 1

I would like to call attention to the fact that I have not fixed upon any definite locations for actual coal mine power houses, but have made assumptions as to the probable minimum distances involved. The actual selection of a site or group of sites might add materially to these distances. The only effect, however, of an increase of 25 per cent to 35 per cent in the transmission distance would be to increase the line losses approximately proportionally to the distance and the cost in proportion to the added length. It would have very little effect in the final conclusions. Since the exact location of a site must be determined by suitable cooling water it will obviously be necessary to make use of a certain amount of railroad haulage of coal. This would be necessary in any case since coal must be collected from a number of mines. This is not objectionable if the coal does not have to be hauled long distances nor over main trunk lines. The west branch of the Susquehanna around Williamsport and Lockhaven is one possible site for a large plant. This plant would be fed from the Clearfield coal district. As an alternative, a power station might be located on the Potomac River somewhat below the Maryland coal fields and the transmission from there to Baltimore would be less than 150 miles. The latter alternative would probably work out to about the equivalent of the other as to cost and as to operating quality.

These two or three generating groups would supply the base load or the maximum continuous 24-hour power for all the territory fed by the main line—amounting to perhaps one-third of the peak load. To carry out this idea with the assumed conditions, the single circuit tap lines should have the maximum possible capacity, which is here taken as 350,000 to 400,000 kw. per circuit. To secure such a capacity at 250,000 volts, requires a number of innovations, which will be discussed later.

It will not be desirable for consumers except the very largest to be connected directly to the 250,000 volt lines on account of complications and the expense. Local consumers in any district can be supplied from the nearest large distributing company. Small water powers or groups of neighboring powers up to 25,000 to 50,000 kw. would be connected with the nearest distributing system without connection to the 250,000-volt system.

As the load in the district grows, additional 250,000-volt circuits can be added from suitable generating sites—probably all more or less widely separated—preferably single circuit lines.

It will be desirable to make use of and depend upon the present large generating stations to supply all peak and breakdown service. Voltage would be independently controlled at the principal points of the system, as for example, Philadelphia, Baltimore, New York, Boston, as will be later explained.

For example, Philadelphia would receive the first tap line and control its voltage and feed the surplus up and down the main line. Similarly with Newark and New York for the second tap line, and also for the third line to the St. Lawrence if this should be later added.

General Features. The new generating plants should be designed for maximum simplicity and low cost. They should be based upon full load operation at 90 to 100 per cent load factor. Turbines and generators should be designed for best efficiency at this load. Boilers should be built for high rating and long continuous runs—with distilled water makeup. Very likely coal should be burned in powdered form and the largest units should be used.

The highest steam pressure, probably 500 lb., with at least 200 deg. superheat and economizers with air heaters for preheating air for combustion from exhaust gases and the heat in the generator cooling air should be used. A house turbine operating condensing with the condensate of the main units for cooling water would be used having as large a capacity as can be handled with the amount condensate available. In addition, atmospheric exhaust auxiliaries would be used to the maximum extent permissible without too high a feed water temperature.

Generators would be synchronous type with governors for controlling the field current, the governors being set for a definite load and the fields controlled automatically to keep a definite power factor—about 98 per cent to 99 per cent lagging and also to take a certain definite amount of charging current at no-load. The reason for this will be explained later.

There would be great advantage in the use of non-synchronous or induction type generators, but their bad power factor and high cost are too much of a handicap to be overcome, unless the characteristics of such generators can be made much more favorable in large sizes than in present sizes; which unfortunately does not seem to be the case.

Large power houses must be located near large and reliable supplies of cooling water—400,000 kw. would require approximately 1500 second-feet flow—or a large lake whose waters could be used over and over, cooling meanwhile.

If a large enough power plant could not be gotten at one point, several closely adjacent plants might be used, all feeding at perhaps 15,000 volts to some central point for stepping up.

High tension transformers would be connected directly to the line—with opportunity of uncoupling the line dead—but no standard disconnect switches. Something in the nature of a very long enclosed fuse might be introduced for short circuit protection

Synchronizing could be done on either end, but on the low tension side, preferably in the new power houses, however.

No means for automatic circuit opening would be provided, except at the six points (7 points if the third tap line be supplied) shown in Fig. 1. At points where one line connects with another, appropriate towers should be placed close together and facilities provided so that the lines could be cut apart in case of emergency.

The transmission lines proposed have a capacity power something like three or four times as large for a given voltage as heretofore proposed. They have the further advantageous property that they transmit normal power with a very small loss of energy or voltage and at the same time will permit only a relatively small current to flow in short circuit. This is a rather remarkable and very useful property. For example, either 150 mile tap line will permit only about three or four times full load with one end short-circuited.

This favorable design of line is obtained only by careful proportioning and if the load on the line be properly chosen. The load is so taken that the charging current of the line neutralizes the lagging effect of the load current in the reactance of the line.* The proper load for this balance can be made to approximate the desired load of 300,000 to 400,000 kw. by using such construction as to give an abnormally large line capacity and a correspondingly small line reactance. The use of aluminum and the dividing of the line conductor into several separated cables or parts

*See *Output and Regulation in Long Distance Lines*, by Percy H. Thomas. TRANSACTIONS A. I. E. E., 1909.

as described hereinafter, sometimes called the "Split Conductor," have a very marked effect to increase capacity and reduce inductance.* This construction also helps greatly in reducing corona and skin effect. Obviously if load and line constants are so chosen that the inductive effect of the line current is balanced by the capacity current at normal voltage, this balance will be lost when a short circuit occurs and the charging current largely disappears. As the charging kv-a. go down as the square of the voltage, and the inductive effect goes up as the square of the current, the capacity effect will be negligible on short circuit conditions, leaving the reactance drop the controlling factor. This explains the favorable behavior of this line to limit short circuits above stated.

The layout of Fig. 1 is favorable, since the general effect of the long interconnecting or main line is to increase the system power factor. Power in large quantities is not regularly transmitted in any one direction over the whole length of the main line but blocks of power will pass in alternate directions in adjacent parts and the drop voltage along this line is practicably negligible. For this reason the capacity will not be neutralized in the main line by the effect of the load current in the line inductance but will be available for power factor correction.

It has just been stated that the drop between any two neighboring large stations on the main line will be very small. This is not only desirable but necessary for when power is to be quickly supplied in reverse direction from normal flow, as for example, on a sudden call for help, this reversal of power could hardly be accomplished practically, if there were a large line drop, since the voltage delivered to the station ordinarily sending out power would be too low to be useful when the direction of power was reversed.

But with a line of very low ohmic drop, like the lines here proposed, transfer of energy backward or forward on the same line may be easily accomplished, for by manipulating the field strengths of the generators on both ends of the line, out of phase or circulating current between the generators can be made to counteract the ohmic drop of the load current. This increases line losses somewhat but line loss would be unimportant at time of emergency and would be small in amount in any case. As a net result of these considerations power can be sent in either direction between two points without changing the voltage at either end, the necessary flow of power being caused by suitable change in the power factor of the passing current.

Operation

As already stated, under normal conditions the new power houses would send current into the main lines in a constant rate 24 hours a day and no changes would be made for load or seasonal conditions. In case of accidents to line,—which should be very rare,—it is proposed that a certain amount of automatic protection would be provided. The transformers at the station which receives power from one tap line are divided into two parts, one connected to the tap line, the other to the adjacent main line. In case of trouble on the tap line, the tap line circuit breaker would open leaving the connection between sections only through the banks of transformers, stepping down through one and up through the other, and then the main line transformers or the tap transformers would be automatically cut off on the low tension side as might be called for, leaving the good line operating. The bad section of the system having been cut out, the good parts of the plant could be operated without the bad part. This would be accomplished by relays.

In testing the insulators and making changes of insulators, it is assumed that this work will be done alive by the method used by Johnson in Georgia. While this sounds chimerical to a person not familiar with what has already been accomplished, I believe it to be entirely possible and safe.

Starting Up. Starting could be readily accomplished on account of the subdivision of the high-voltage lines. Philadelphia will excite the section of the line to Newark by the low-tension switches through one set of transformers. This is too short in length for the charging current to be important and will furthermore merely relieve the lagging power factor of the Philadelphia system without increasing load or current. New York can then synchronize with Philadelphia on the low side. Philadelphia will then excite first tap line on its second bank of transformers. This will call for no increase of current at Philadelphia as before on account of the great excess of load lagging current. By connecting the power house transformers at the coal mines before exciting the line, no synchronizing on high voltage would be necessary. Newark or New York would similarly excite the second hard coal tap line (and the third if installed). The line in Baltimore may then be energized at Philadelphia and Baltimore synchronized on the low-tension side. Similarly with the line to Boston, and the system is operating ready for load. The two tap lines which so far are connected only by step up transformers would be connected to the main line at leisure by the high-tension circuit breakers, the system being already synchronized.

The switches or breakers shown in Fig. 1 can be used for automatic cutting apart of the sections of the high-tension system as already explained. On account of the characteristics of the transmission lines as here laid out, these coal mine stations will add little to the short circuit currents; and one center like New York will supply little short circuit current to another as Philadelphia.

Spare Lines. This scheme of Fig. 1 offers no spare lines. It is not believed that the expense of a spare line is warranted. It will be noticed that no accident

*TRANSACTIONS A. I. E. E., 1909, loc. cit.

at any one point of the line can cut out more than a small part of the system except momentarily—nor more than one of the mine power plants. If the system grew it would be possible to add other tap lines at suitable points, which would reduce the power shortage due to any failure without providing any idle lines. It would probably be more economical for the community as a whole to make the best shift possible to a certain extent in case of a serious line failure than to pay the charges and endure the disadvantage of the complication of spare lines and additional switching facilities.

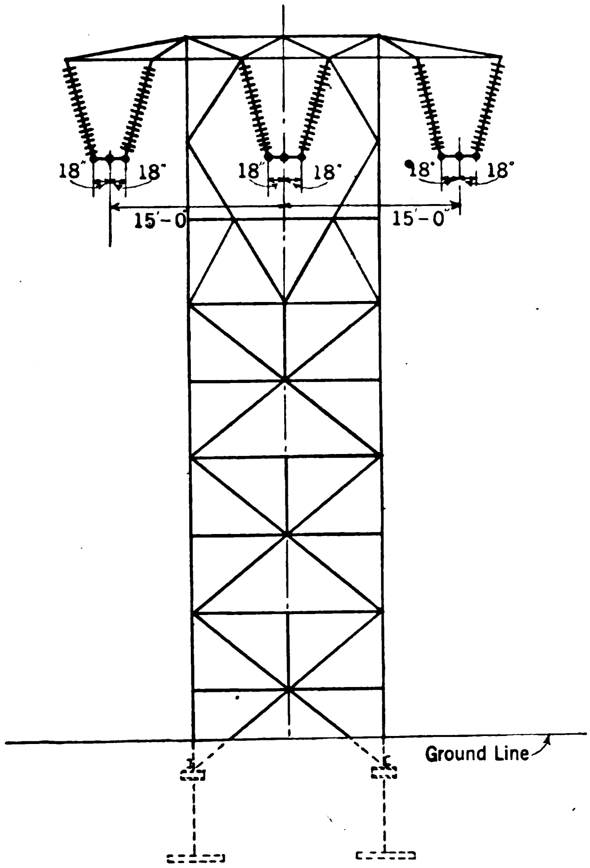

FIG. 2

Transmission Line. The conductor has been chosen as consisting of three 600,000-cir. mil. aluminum with steel cores. These would be placed in a horizontal plane, 18 to 24 in. apart each hanging from two strings of insulators suspended at an angle, as shown in Fig. 2. This would reduce side swinging and help clearances. Furthermore, if one insulator string should be broken the other would hold up the conductors.

The principal strain on the towers, according to the usual test specification, is due to a broken conductor causing torsion. To reduce this requirement and so lighten the towers as far as possible—suspension towers should be arranged with the conductors free to slide in the hanger, or held only by a moderate grip, having a maximum positive hold. The conductor will tend normally to equalize longitudinal stresses in the adjacent spans automatically and not to develop unevenness. The one danger is the uneven collecting or falling of ice and sleet. A moderate grip on the hangers such as would be justified by the strength necessary in the tower for other requirements would be sufficient to prevent any permanent slipping except in case of a conductor broken in all three cables. In this case the conductor will slip in one or more hangers and drop on the ground. The drag on the ground will prevent the line slipping in many towers. Repair in any case will be a big undertaking. The breaking of a single cable of the three of any phase would cause an electrical ground but no slippage.

The assumptions here made are confessedly a departure from standard practises of the present and mature discussion may or may not prove them warranted. The results accomplished will be somewhat less installation cost, with, I believe, no material increase in the danger of line interruption, this being account of the special hanger or cable clamp assumed.

For most economical construction all ground wires should be omitted. Whether the installation of ground wires would eliminate enough trouble to warrant the expense and complication introduced is a debatable point. It is probable that indirect or induced surges will not be sufficiently severe to affect the lines, since the lightning effects do not depend primarily on the line voltage and since disturbances of this nature on our highest voltage lines seem comparatively rare. Direct strokes of magnitude will not be turned aside by ground wires and the most that can be expected of ground wires would be the elimination of certain disturbances of intermediate severity.

The 150-mile tap lines as shown when delivering 300,000 kw. at 250,000 volts and 99 per cent power factor lagging will have an energy loss of 3½ per cent and a drop of about 5 per cent and the generator power factor unity. It is essential that calculation of this line be made by an accurate formula, such as the hyperbolic function method, taking account of distributed inductance and capacity. Formulas based on localized capacity will give misleading results. The critical condition to cause this failure of the approximate formulas is the one here existing, *viz.*, that the leading and lagging effects of capacity and inductance balance, leaving substantially ohmic losses. With the reactance seven times the resistance the importance of this consideration is evident.

With 400,000 kw. delivered, the energy loss would be 5 or 6 per cent and the line drop about 9 per cent. With 300,000 kw. and a lower power factor the efficiency would go down and the line drop up, but a considerably lower power factor would not give unduly unfavorable conditions. It is here assumed that the existing generating apparatus when coupled up with these lines will be able to supply the necessary out-of-phase current to permit a high power factor in the delivered line load. If not, synchronous condensers can be used as is now customary. With a lightly loaded

line the automatic power factor control on the coal mine generators already described will secure a condition such that there will be almost no voltage change between light load and full load at the power house. Since voltage is established at the receiving end there will be no voltage variation there.

The essence of this arrangement is that the coal mine generators shall be set to take automatically a definite power factor at and near full load and yet will take automatically a certain amount of charging current at or near no load. These adjustments should be so made that with full load a slightly lagging power factor shall be maintained automatically at the receiving end of the tap lines. With the voltage regulating apparatus of the distributing system at the receiving end in entire control of the delivered voltage the system will maintain itself in proper adjustment to give the efficient line conditions required—that is approximately unity power factor in the line.

Costs. It having been established in the general terms that the operating characteristics of the super system as proposed are satisfactory and in many ways unexpectedly favorable, the questions of capital and operating costs remain.*

Capital Cost. It may be assumed that a 400,000-kw. power station may be built, under reasonably favorable price conditions for $100 a kw. including overhead necessary for design and construction; that the transmission lines as proposed, *viz.*, two 150-mile 250,000-volt, 400,000 kw. tap lines and 100 miles of similar capacity line for the central part of the main connecting line, and 250 miles of 200,000-kw. line, can be built at an average cost of $47½ a kw. generated, including overhead. Also that the necessary 250,000-volt step up and step down transformers with 250,000-volt switches could be installed for $15.00 a kw., giving the following table:

	Per kw.	
2-400,000 kw. power houses	$100.00	
700 miles 250,000-volt transmission lines	47.50	
250,000-volt transformers and switches	15.00	
Miscellaneous	1.50	$164.00
Total for 900,000 kw., allowing 12½ per cent spare		$150,000,000.00

Taking into account the added cost of real estate, the congestion of fuel handling in the large cities and the complication of handling large blocks of power underground from city stations, a fair estimate of the cost of installing plants to generate this same amount of power at the several large centers, supposed to be supplied, would be about $125.00 per kw., leaving an excess capital cost on account of the transmission scheme of $40.00 per kw., a very small amount for the benefits offered. The value of the 800,000 kw. delivered to the large distributing companies should be in the neighborhood of $20,000,000 to $25,000,000 a year, with present or slightly better conditions.

These cost figures are fairly liberally estimated on the basis of routine construction, probably 10 to 20 per cent should be added to cover additional cost due to the unusual character of much of the work.

Comparing the cost of transmitting the power over transmission lines with the cost of hauling coal by rail, we have to compare the freight on five tons of coal (a sufficient quantity to produce a kilowatt for a year) against the cost of 10 per cent additional coal (required to cover losses in transformers and transmission) plus $3.50 fixed charges on excess capital cost of one kilowatt for the transmission system. That is with coal at $1.00 per ton at the soft coal power station, five and one-half dollars worth would be required for each kilowatt-year. Adding $3.50 excess or fixed charge, gives $9.00. For coal hauling to be on an even basis, coal freight would be 80 cents a short ton. Most of this is on account of interest on the excess investment. This, however, charges the transmission system with 700 miles of line while the actual distance of transmission is only 2 × 150 miles. If the cost of 150 miles, the direct transmission only, is considered, the capital cost may be taken as 12½ per cent less, giving a fixed charge of $2.00 a kw. and a corresponding freight rate of 50 cents a ton. All the above figures are in short tons.

I wish to say that all the above dimensions and estimates are based on the assumption, that the inter connecting system will be characterized by extreme simplicity and that very little so-called flexibility will be provided. This is necessary to reduce costs and to simplify operation and is justified by the completely equipped plants already operating in the interconnected district.

These approximate figures give an idea of the actual and relative cost and of some of the results that might be obtained by interconnecting the district and supplying from the coal fields the base load for two or three million kilowatt of maximum load now existing. With the future growth of the load and the electrification of the railroads, the St. Lawrence development, or additional coal mine plants, might well add another half million kilowatts in one or two circuits, on a basis more or less on a par with the above, except that if the new power should be hydraulic, it would probably call for a somewhat larger capital expenditure and would show a lower operating cost.

Attention is again called to the fact that the present discussion is based on a hypothetical typical case and not on an actual group of definitely located power houses. Variations of 25 to 50 miles in the length of transmission will, however, make little difference in the net result.

*In this present discussion very free use has been made of the excellent paper, *Problems of 220 Kv. Power Transmission* by A. E. Silver, A. I. E. E., 1919.

It is to be hoped that as the cost of generating electric power is reduced, partly by the development of such large scale systems as here discussed, partly by the natural development of the art, and partly also by the freer use of local distribution mains, that the use of electric power for heating and cooking and small power will be enormously increased, which will warrant the building of the largest systems, becoming a great source of comfort to the community.

So far no account has been taken of the benefit from the inter-connecting system here under discussion in its opportunity to take advantage of diversity factor in general power consumption nor of its very great advantage in raising the load factor of a railway load, which is at best very low. The relay and breakdown service of the interconnecting line would be of great benefit. Another advantage accruing is the ability of the system to apply a surplus of power existing in any one system, either temporary or permanent, to any load that may be available. This ability is of much importance in a growing district. Furthermore, the ability to locate very large consumers of power at the most favorable location would be of importance. For example, a large electric furnace plant can now only be placed near some large system, without installing a special power plant. Other similar advantages of the interconnected system exist, but enough has been said to warrant a careful study of its advantages, disadvantages, possibilities and limitations.

8. W. D. PEASLEE

High-Tension Insulators

The utilization of 220,000 volts or higher for the transmission of power is not a problem that holds any terrors for us as insulator manufacturers.

Due to the size of the cable necessary on such a line and to the fact that it seems rational to design the line for more severe storm loading conditions than standard for an ordinary line, the standard disks suspension insulator as at present manufactured is not entirely satisfactory from a standpoint of mechanical strength.

An insulator for 220,000 volts will have to stand very severe operating conditions as to mechanical stresses and dielectric flux concentrations, and it is very important that certain features of insulator design be followed carefully in any insulator presented for this service. Due to the large size conductors necessary and the spans, the mechanical stress will be considerably in excess of that met with in high-voltage lines now in operation.

The ratio of puncture to flashover in any unit is a very important feature of its design and one which unfortunately has been neglected in most conventional designs of insulators. Due to the effect of transients added to the normal frequency voltage of the line and their time lag or impulse ratio, it is possible to stress the end unit of a string to very high values, and for that reason its actual puncture resisting power should be very high. The puncturing voltage of a disk insulator for such service should never be less than 2½ times the dry flashover voltage of the unit.

In order to reduce corona formation as much as possible, the unit should be designed to reduce the flux concentration and in such a way that the corona forming voltage will be considerably above the operating voltage impressed upon the unit.

For an insulator for service of this kind strength is an important factor. The lines are very important and the ability of the insulator to withstand power arc shock and other events, is of the greatest importance to the continuity of service of the line. We have made a very careful study of the requirements of this insulator.

We are at work at the present time on a disk insulator to meet this requirement. It will be a disk insulator probably of larger diameter than the present design, with a mechanical strength sufficient to meet the strains imposed by the larger loadings necessary in such a line; dry flashover in the neighborhood of 125,000 volts. It will be designed in accordance with the correct theory of surface design between the air and porcelain, and with this design the corona-forming voltage will be very high. The approximate puncture voltage per disk will be in the neighborhood of 300,000 volts, thus securing the high ratio of puncture to dry flashover now recognized as a vital point in correct insulator design.

From these characteristics you will see that this disk will be very well suited for this particular work and our research work has progressed far enoush so that we feel confident that by the time such a line is an active proposition, we will be able to undertake the insulation problem. Not more than eight to ten units will be required for the 220,000-volt grounded Y line and this will give a string of insulators from 65 to 80 in. in length.

9. A. O. AUSTIN

High-Tension Transmission Systems

It would seem that the super-power project such as Mr. W. S. Murray has outlined, must become more and more of a necessity with each succeeding year. The project would necessarily change in character in time, but the sooner it is started, the greater the saving that would be effected, both as to the economy of operation and the saving of natural resources. The very magnitude of a system of this kind tends to postpone a start on the project, even though the possible economies increase with the size and completeness of the system.

The project must necessarily depend upon an efficient transmission system, and as the cost of the connecting transmission line will be an important factor, it is necessary that we consider the state of the art with a view of adopting a transmission system which will show a maximum economy. Anything effecting the cost of the transmission system should be given careful

consideration, for the greater the economy shown the more quickly will a system of this kind be put in operation. Where a project of this magnitude is involved it would seem that a departure from the usual practise is well warranted, particularly where an increase in reliability and a decrease in cost can be effected.

It is possible that at the start, a large part of the system could be connected to advantage with a transmission line not exceeding 110 kw. It is probable, however, that power will be transmitted from large hydroelectric or steam plants located at a considerable distance. The increasing cost of coal will make it highly advisable that the future additional generating equipment be located where the greatest economy can be effected, rather than split up into a lot of smaller, less efficient stations.

The adoption of a high line voltage for the main trunk system would show a saving which might hasten the project several years, consequently it is important that we consider various factors which may be taken advantage of, to increase the efficiency or lower the cost of the line.

The real problem on a large transmission system operating at a high voltage, has usually been that of regulation, and it would seem that the present project is no exception to the general rule. It would seem that the future demands for power in the zone covered by the project would permit the installation of equipment without additional cost, which would give the necessary regulation to insure the success of the system All that would be necessary would be to form a comprehensive plan and install future equipment so as to make the scheme effective.

A transmission line operating at 220 kv. or slightly above will involve large conductors, which would give the system a high degree of mechanical reliability not afforded in the smaller systems. In addition the insulation which would be necessary for the line and equipment, would make the system free from lightning trouble. These two factors would be important in eliminating the necessity for stand-by plants, and should hasten the adoption of the project. The large amount of power would permit of apparatus of a high degree of strength and reliability, so that shut-downs from failure of same would be negligible.

A careful analysis of operating systems would probably indicate that the greatest danger to a system of this kind would be that due to suddenly dropping a large portion of the connected load. This hazard could probably be entirely eliminated by tieing in the main transformers connected to the system, so that they could not be disconnected by the operator unless the voltage of the system was lowered or a defective unit alone be disconnected. Since apparatus would probably be disconnected only in case of failure, a shunted fuse or other inexpensive device could be used to disconnect the defective unit. This would eliminate a considerable cost for oil switches and the freedom from lightning would probably permit the elimination of lightning arresters. This would effect a considerable saving and might advance the installation of the completed project several years.

It is highly desirable to make the main system simple to give the highest degree of reliability and it would seem that in carrying this out that economies could be effected which would more than off-set the increased cost for the higher voltage transformers necessary to permit an economic transmission system for supplying power for a considerable distance. The large conductors necessary for a system such as this would require heavy working stresses for the insulators. The insulator art, however, is such that high ultimate insulators with longer life can be produced at a much lower price than they could previously. It is now possible to procure insulators such that a single string will carry the line and at a cost probably not more than 50 to 60 per cent of that required for a 110-kv. line. From this it will be seen that the cost of installation for a 220-kv. project would probably be less than the cost of some of the 150-kv. lines previously installed. The transmission art has advanced rapidly and many economies could be effected by carrying out a comprehensive scheme, which are not possible in many of the existing systems.

Large additional amounts of power will be required in the district effected by the project and much could be saved by adopting a plan as soon as possible. It would seem that there is no new or untried principle involved, and that by making a survey it would be possible to show the economies which would be effected not only for the present, but for some years to come. It takes considerable time to put large projects into operation, hence it is important that we do not confine our attention entirely to the immediate economies, but look more to the future.

The Baldwin-Westinghouse Chicago, Milwaukee & St. Paul Electric Locomotives

BY N. W. STORER

General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Requirements

In the summer of 1917, the Chicago, Milwaukee & St. Paul Railway Company issued specifications covering the apparatus necessary for the electrification of their line from Othello to Seattle and Tacoma. The following were the principal requirements for passenger locomotives as finally determined by the Railway Company:

Power Supply. To be 3000 volts direct-current.

Route. Either the line between Harlowton and Avery, or the newly electrified line from Othello to Tacoma and Seattle.

Grades. The limiting grades are 2 per cent compensated for a distance of 20 miles from Piedmont to Donald on the east slope of the Rocky Mountains, and 2.2 per cent compensated for 17.8 miles from Beverly Junction to Boylston on the western division.

Alignment. The sharpest curve on the main line is 10 deg., but the locomotive must negotiate a 16 deg. curve in the yards satisfactorily.

Load. Twelve steel coaches weighing 950 tons.

Speed. The locomotive to be designed for a speed of approximately 25 mi. per hr. up a 2 per cent grade, about 35 mi. per hr. on 1 per cent grade, and to have a maximum speed of 65 mi. per hr.

Mechanical Design. The locomotive to have a four-wheel guiding truck at each end, of the "Woodard" type.

The driving wheels to be not less than 60 in. in diameter.

Regeneration. Trains to be held on down grades by regenerative braking.

Train Lighting. Current to be supplied from the locomotive for lighting the train and charging the train storage batteries at a voltage of 60 to 85.

Train Heating. The locomotive to be equipped with an oil-fired boiler, to be supplied by the Railway Company, to furnish steam for heating the train.

Storage capacity to be provided for 30,000 lb. of water and 750 gallons of fuel oil.

Thermostats. Thermostats to be provided that will automatically start the blowers for cooling the main motors when the motor temperature reaches a pre-

Fig. 1—Baldwin-Westinghouse 3000-Volt D-C. 275-Ton Passenger Locomotive for Chicago, Milwaukee & St. Paul Railway Co.

determined value, in order to limit their operation to that time when they are actually needed.

Description

A portion of the order for locomotives was secured by the Westinghouse Electric & Manufacturing

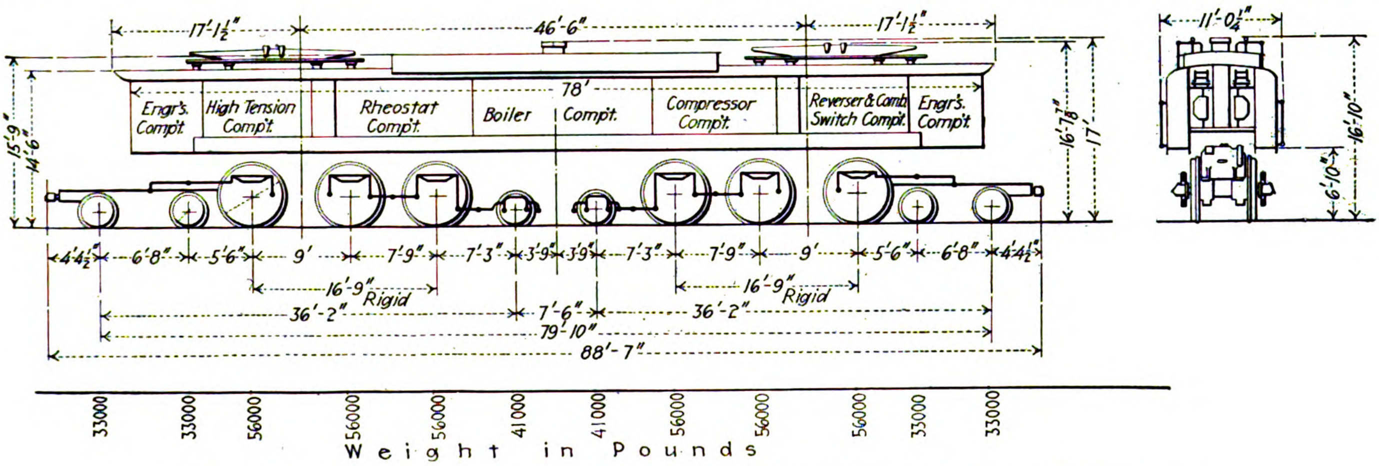

Fig. 2—Outline Showing Equalization Scheme, Weight Distribution and Wheel Base

Company, and this paper covers the brief description of the Baldwin-Westinghouse locomotive as furnished.

General. A view of the complete locomotive is shown in Fig. 1, and a diagram showing the wheel arrangement, axle loading and equalization, in Fig. 2.

The locomotive is built in a single unit, having

Presented at the Pittsburgh meeting of the A. I. E. E., March 12, 1920.

one long cab, carried on running gear of the 4-6-2 – 2-6-4 type.

The locomotive weighs 275 tons.

Main Running Gear. The running gear consists essentially of two Pacific type running gears, coupled back to back. One-half of the running gear is shown in Fig. 3. This shows the running gear complete with the motors mounted and the air conduit carried on top of the motors.

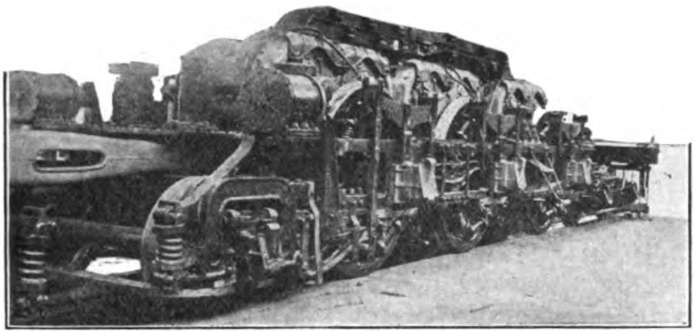

Fig. 3—One-Half Locomotive Running Gear, Showing Driving Motors, Coupling Bar and Air Conduit

The side frames are steel castings, joined over the four-wheel trucks by a heavy "A" frame casting; also by heavy cross-ties between the drivers which also support the motors, carry the center pin and carry the coupling between the two running gears.

Each half running gear has six spring-supported plungers on which the cab rests. There are two supports at each end and two in line with the center pin. By the use of shims, the distribution of weight between the two ends of each running gear may be adjusted as desired.

The equalization, as shown in Fig. 2, is of the standard three-point type; the leading bogie being cross equalized with the leading pair of drivers and the pony axle being equalized with the two adjacent driving axles on the sides.

Extra points are provided in the equalizing levers so that practically any distribution of weight that is desired can be attained.

The driving wheels are 68 in. in diameter; the journals 8½ in. by 14½ in., located outside of the wheels.

The drawbars, with Minor fraction draft gears, are carried in the "A" frame casting, previously mentioned.

The coupling between halves of the running gear consists of a long bar of a box section. This is shown in Fig. 3. The coupling pins are 10 in. in diameter and are located well inside the pony axles. The pins are hollow, filled with oil-soaked waste and have oil holes provided that keep the pins well lubricated.

Bogie Trucks. The four-wheel trucks are of the "Woodard" type with outside journals; 36-in. rolled steel wheels and cast steel side frames. The journals are 6½ in. by 14 in.

Pony Trucks. The two-wheel truck is of the well known "Rushton" side-bearing type, also with outside journals and 36-in. wheels. The journals are 6½ in. by 14 in.

Brakes. Brake shoes are provided on all drivers. A modified form of the 14-EL Westinghouse Air-Brake Company equipment is used.

Cab. The cab is 78 ft. 0 in. long, 10 ft. 2 in. wide; is strong and rigid so that it can be lifted at the ends. The main strength lies in the two bridge girders extending from end to end. The heavy cross-braces and the side members and top of the raised deck down the middle of the cab, form a construction that is light, but stiff. The cab is divided by cross partitions into compartments, one at each end for the engineer, and the others for the various parts of the cab equipment.

Locomotive Capacity. The total motor rating of the locomotive is 4200 h. p. on the one-hour basis. The continuous rating is 3400 h. p. The tractive effort and the speed are given on the nameplate of the locomotive as follows:

Rating	Tractive effort		Speed	
	Full field	Short field	Full field	Short field
1-hour rating	66,000	57,000	23.8	27.2
Continuous rating	49,000	40,800	26.0	30.4
Weight on drivers	168 tons			

Electrical Equipment

Driving Motors. The six driving motors are of the twin armature type. See Fig. 4. Both armatures are contained in a single frame, arranged to secure the maximum economy of weight. The fields are of the standard four-pole type with four salient poles and four inter-poles for each armature. There are brush-arms on each commutator which are easily accessible.

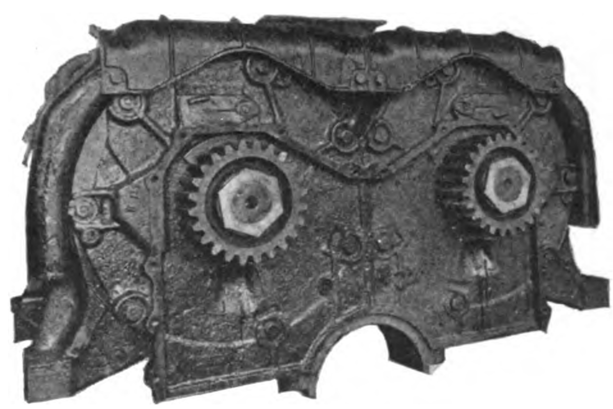

Fig. 4—700-H. P. 1500/3000-Volt D-C. Twin Armature Motor

Each armature is wound for 750 volts, but the two armatures and the two sets of field windings are connected permanently in series so that the rating of the complete motor is based on 1500 volts.

The motor is designed for field control by means of inductive shunts.

The one hour rating is 700 h. p. The continuous rating is 567 h. p. with forced ventilation and 400 h. p. without blowers.

The characteristic curves, when running as a series motor, are shown in Fig. 5. Curve sheet Fig. 6 shows the performance when regenerating.

Quill Drive. The motors are mounted rigidly on the cross ties of the running gear, one directly above each driving axle. Each motor is geared to a quill centered in bearings in the motor frame and surrounding the driving axle with a clearance all around when axle and quill are concentric of 1¾ in. The quill is connected to the drive wheels by long helical springs which are clamped rigidly at the ends in castings which are

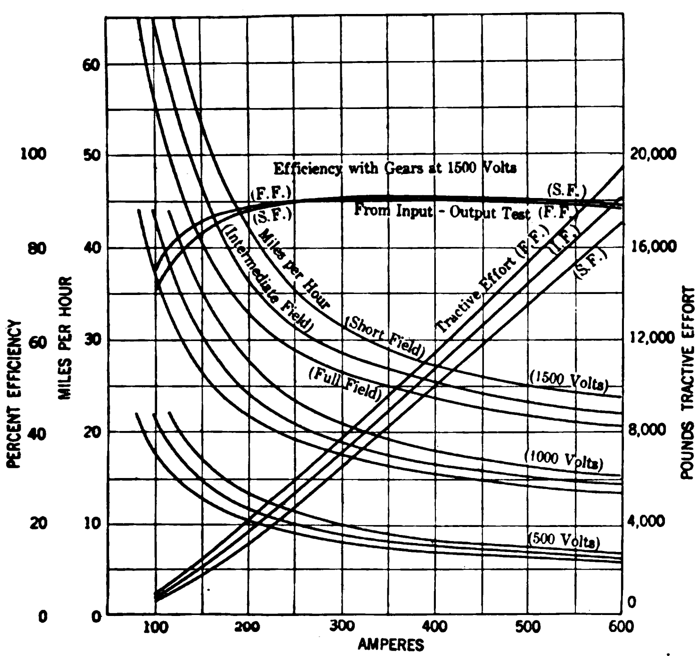

Fig. 5—Motoring Performance Curve of Driving Motor at 1500, 1000 and 500 Volts

bolted one to the quill flange and the other to the drive wheel. There are seven springs at each end, worked in compression in one wheel, while those in the other are in tension. All springs with clamps are interchangeable. They are easily accessible for inspection, and any spring may be removed without disturbing any other part of the running gear.

This drive is similar to the well-known quill drive of the geared locomotives of the New York, New Haven & Hartford Railway.

Main Motor Control. A schematic diagram of the main motor circuits with starting resistances and all stabilizing resistance and exciters for regenerative braking is shown in Fig. 7. The six motors are arranged to be connected in three combinations:

1. All in series, giving one-third speed.
2. Three in series, two in parallel, giving two-thirds speed.
3. Two in series, three in parallel, giving full speed.

Inductive shunts are applied to the fields on all three of these positions.

Shunt transition is used in passing from one combination to the next.

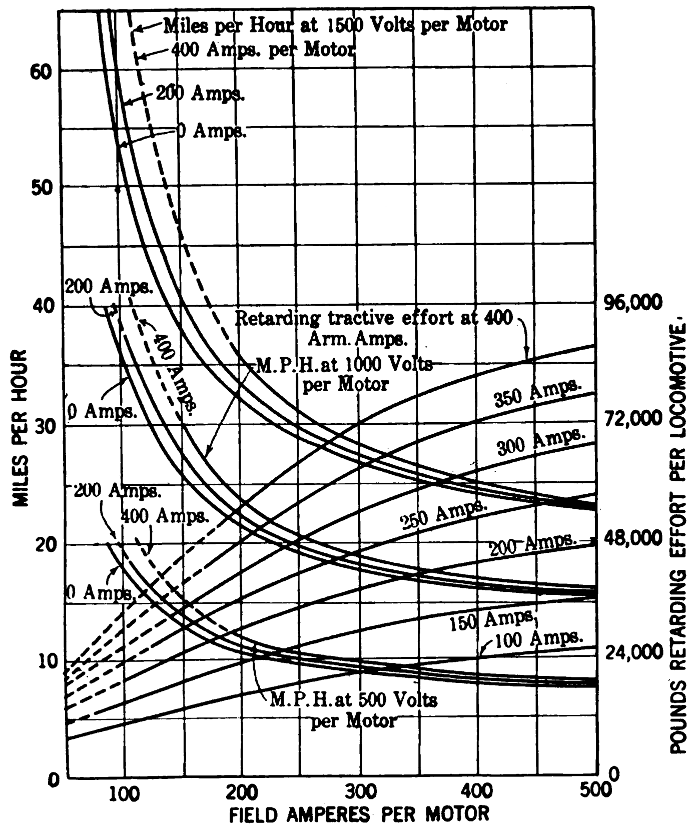

Fig. 6—Regenerating Performance Curves of Locomotive with 3000 Volts on Line. Speeds with First, Second and Third Motor Combinations. Current Shown is Current per Motor

Regenerative Braking. When regenerating, the motors are separately excited from two axle-driven generators which are carried on the inside axles of the two four-wheel trucks and geared to them like ordinary interurban railway motors. These generators are

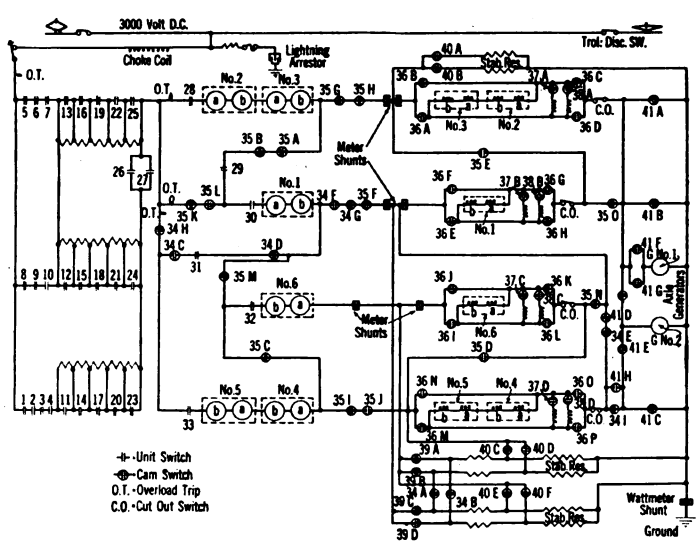

Fig. 7—Schematic Diagram of Main Motor Circuits

separately excited and the field strength of the main motors is controlled by varying the fields of the exciters.

The scheme that is used for regeneration includes the use of stabilizing resistance, which is connected in series with the exciter armature, main motor field circuit, and also with the main motor armature circuit, so that the field excitation is dependent, to a certain extent, on the armature current. A schematic diagram of this is shown in Fig. 8.

Master Controller. The master controller is shown in Figs. 9 and 10. It has four control drums and four operating handles.

1. The speed drum, which controls the resistance switches and line switches; field shunts during motoring and the exciter voltage during regeneration.
2. The reverser drum, which performs the usual function.

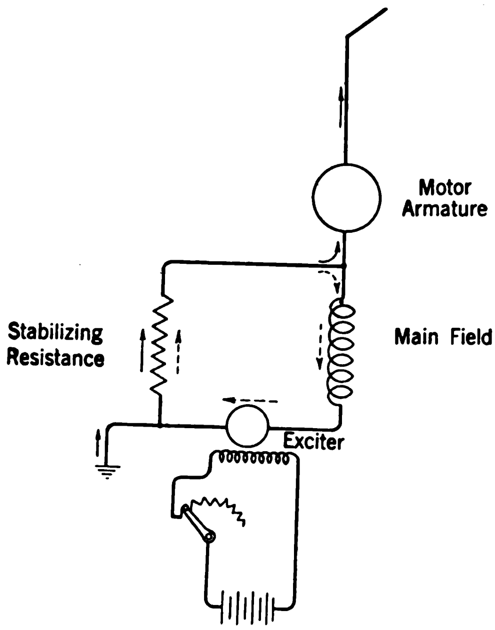

Fig 8—Simplified Schematic of Regeneration Connection

3. The motor combination drum, which has three positions, each corresponding to one of the three motor combinations.
4. The regenerative drum, which changes the connections from motoring to regenerating and vice-versa.

The master controller is arranged so that the controller may be thrown from the "off" position to the second or third speed combination, if desired, without passing through the lower combinations.

The method of operation is as follows:

To Start the Train. Motor combination lever in first speed position; regenerative lever in motoring position; the reverse lever in forward position.

Move the speed lever to the first notch and gradually notch up until the train starts and then continue until the resistance is all cut out and the train is running with the motor field shunted in the first motor combination.

Then throw the motor combination lever to the second position; back off the speed handle to the first position (at the same time pressing a button in the end of the lever so that it cannot pass the first position).

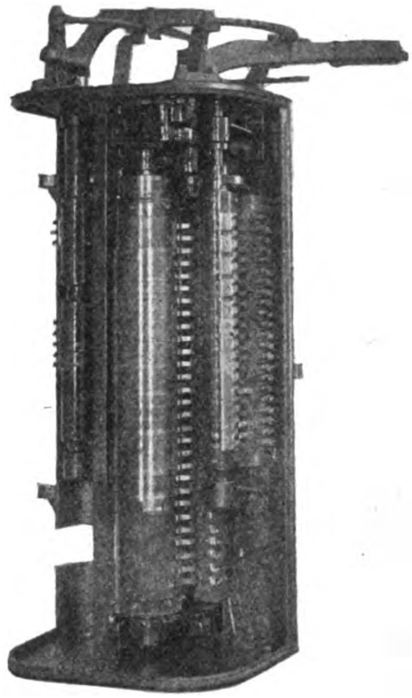

Fig. 9—Master Controller with Cover Removed, Showing Drums for Speed Control, Reversing, Motor Combinations and Regeneration

At that point, with the resistance all in circuit and the three legs of resistance in parallel, the change-over takes place; one-half of the motors being shunted momentarily and then thrown in parallel with the

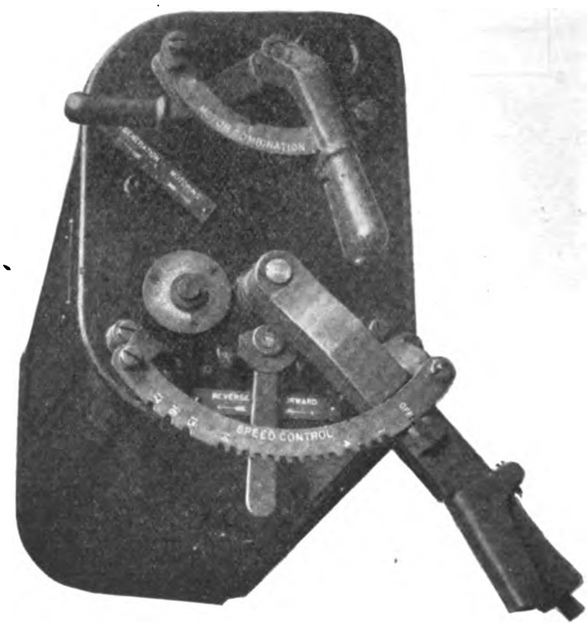

Fig. 10—Top View of Master Controller

other half. The resistance is then notched out as before and the motor-fields shunted.

Then the motor combination handle is thrown to the third position and the speed handle backed to the

fourth notch when the change is made from the second to the third combination, and the resistance speed handle again notched forward. With the resistance all cut out, the motors may be run with full field or first or second shunt.

The engine-man is prevented from accidentally starting the locomotive from rest, in the second or third combination, by an interlock in the controller which prevents the line switches from closing when the motor combination lever is in the second or third position, unless he pushes a button in the top of the master controller.

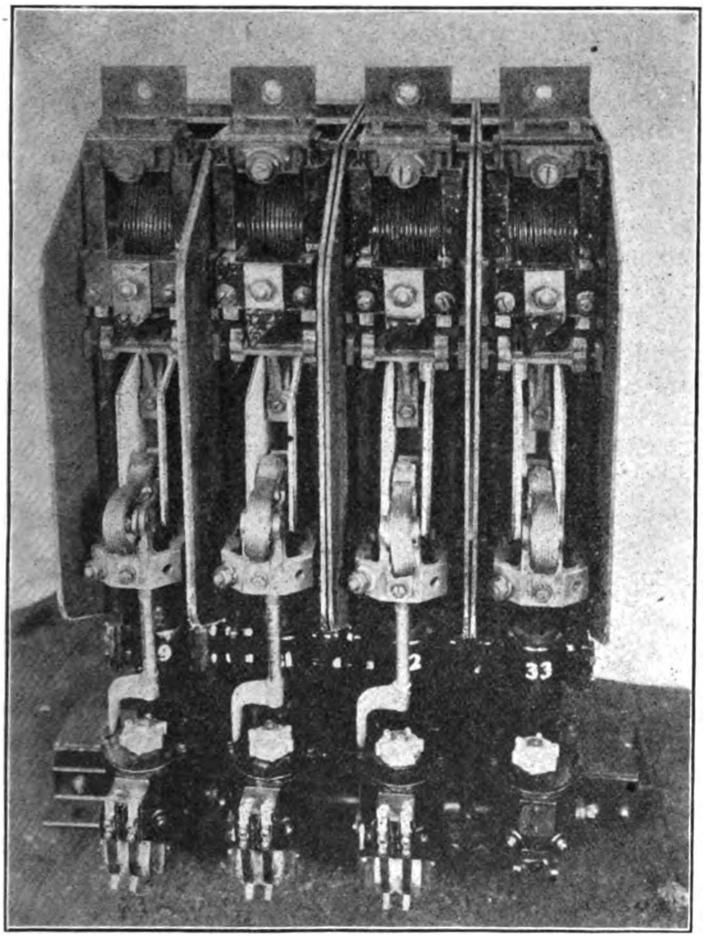

Fig. 11—Rear View of Group of Four High-Voltage Unit Switches

It is, therefore, necessary when applying current with the locomotive at speed, to press the button when it is desired to go immediately into the second or third combination.

There are thirteen resistance steps, all of which are available in both first and second speed combinations. On the third combination, there are ten steps that are useful; making a total of thirty-six resistance steps and two field shunting notches in each combination, or a total of forty-two steps in the master controller. The ease of manipulation of this arrangement of master controller has already been established in service.

Main Resistance. The main resistance is arranged in three groups, each of which has five switches, each short-circuiting a section of resistance. These three groups are connected all in series for the first combination, and three in parallel for the second and third combinations. The sequence of closing the resistance switches is the same on all combinations. The resistances are always connected in series before the master controller reaches the "off" position.

Overload Trips. The overload trips are arranged to open the resistance switches and insert the entire resistance in series before the line switches are opened.

Regeneration. The operation to begin regeneration is as follows:

1. Throw the regenerative handle to the regenerative position on the master controller.
2. Place the motor combination handle in position corresponding to the speed of the locomotive.
3. Move the speed lever to the first step. This connects the motors to the line with all resistance in series and with the motor-fields excited with the minimum exciter voltage.

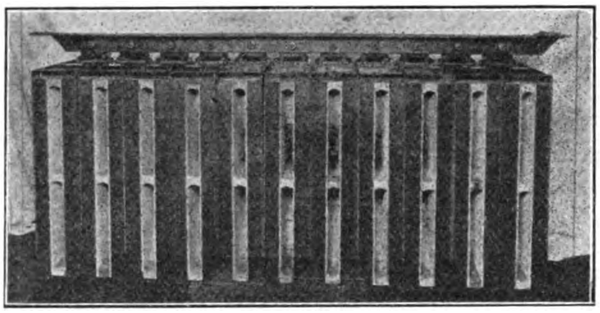

Fig. 12—Front View of Unit Switch Group

The exciter voltage is automatically increased until the motor voltage equals the line when the speed lever is moved to the sixteenth notch of the controller, after which the exciter voltage and speed can be changed by the engine-man by moving the speed handle alternately back and forth between the sixteenth and the seventeenth notches, if the exciter voltage is to be decreased; or between the sixteenth and the fifteenth, if it is to be increased. The motor-operated rheostat will move one step for each time the controller is moved.

To change the motor combination during regeneration, throw the speed handle to the "off" position; move motor lever to the new position and start regeneration as before.

Unit Switches. These are shown in Figs. 11 and 12, and are indicated on the diagram by two vertical dashes. The switches are numbered from "1" to "33". The switch is provided with a very powerful magnetic blowout with arc chutes of arc-resisting material, and an arc splitter. It is electro-pneumatically operated and is designed so that it is very thoroughly protected from insulation troubles and for ease of inspection and over-hauling.

Cam Switches. The cam switch groups are shown in Figs. 13 and 14, and indicated on the diagram by two vertical dashes enclosed in a circle. The switches are designated by numbers and letters. The number corresponds to the group in which the switch is placed and the letter corresponds to the particular switch in the group.

Those of Nos. 37 and 38, which are the groups operating the field shunts, also Nos. 39 and 40 which control the stabilizing resistance during regeneration, are provided with magnetic blowout; but the switches

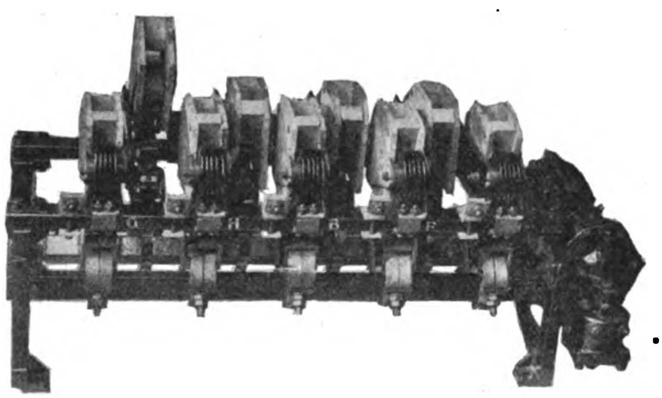

FIG. 13—CAM OPERATED SWITCH GROUP WITH MAGNETIC BLOWOUTS

for the reverser, which never close or open the circuit with current on, have no arc chutes or blow-outs. Groups Nos. 34 and 35, which make the different motor combinations, have barriers placed between adjacent switches which have a large difference in potential, but no magnetic blow-out, since these switches are never used for opening the circuit under load. The groups are operated electro-pneumatically.

Auxiliaries. Power for the auxiliary motors, control circuits, train lighting, motor excitation, etc., is derived from three sources:

1. *Motor-Generator.* (See Fig. 16). The motor receives current from the line; the generator delivers current at a constant voltage of 85. This is required primarily for train lighting.

2. *Storage Battery.* Of the MV-25 ironclad Exide type containing 38 cells. This battery has a capacity of 300 amperes for approximately one hour.

3. *Two Axle-driven Generators.* Which are designed primarily to furnish current for exciting the main motors during regeneration.

The storage battery is always available to supply current for locomotive lights, control circuits, and the air-compressor motor for short periods. When the locomotive is in service, the generator of the motor-generator set is always in parallel with the battery, and from this dual source is always taken the power for lighting the locomotive and train, control circuits, cab floor-warmers, small blower motors for inductive field shunts, boiler blower and exciting current for the axle generators. In addition, the current for the air-compressor motor is supplied from this dual service whenever the locomotive is standing still or regenerating.

The axle generators are, as stated, used primarily for exciting the main motors during regeneration. At other times, when the locomotive is in motion, the axle generators are automatically connected to the auxiliary circuits from which the compressor and main blower motors take power. At this time the voltage is automatically maintained at 90.

Air-Compressor. A two-stage compressor with intercooler, having a displacement of 150 cubic feet per minute, is provided. It is a double-acting, upright type, driven by an industrial type motor.

Blowers. Two blowers are provided to supply forced ventilation to the driving motors. They are driven by motors that are duplicates of the compressor motor.

Auxiliary Control. The axle generator circuits are shifted from one circuit to another by a group of the same type of cam operated switches as are used in the main motor circuits.

The field rheostats for the generator of the motor-generator set and the axle generators are operated by small motors. As the fields of the two axle generators are connected in series, only one rheostat is required for them.

The switches for controlling the blower and compressor motors and the high-voltage motor are magnetically operated.

The motor of the motor-generator set is protected from overload or short circuit by a small permanent

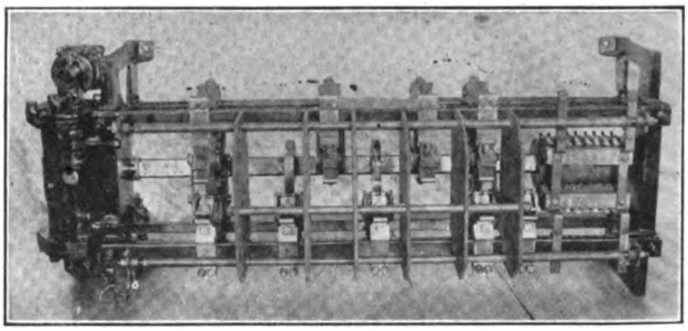

FIG. 14—CAM OPERATED SWITCH GROUP WITH BARRIERS

resistance in series and a set of three expulsion type fuses which blow in series, the first two inserting additional resistance in the circuit, and the last opening only after a relatively high resistance has been inserted and the current consequently limited to a low value.

Meters. A Sangamo wattmeter is provided which has separate dials for integrating the motoring watts and regenerating watts. A full set of motor ammeters is provided, and also a voltmeter reading line volts. An ampere-hour meter is provided for the storage battery.

Train-Heating Plant. A boiler with a capacity for

evaporating 4000 lb. of water per hour is provided for heating the train and engine-man's cab. The boiler and water storage tanks are located in the middle of the cab and occupy a relatively large proportion of the space. The tank for fuel oil is located directly beneath the boiler, and the water tanks, two in number, just fore and aft of the boiler.

Pantagraphs. Two pantagraphs of the double sliding shoe type are provided. These are raised by air and lowered by gravity.

Wiring. All cable is in steel conduit, and all exposed connections are solid copper bar or strap.

6. The minimum permissible restraint to free movement of each axle and portion of the running gear.
7. Large diameter of drivers and low "dead" weight on axles.

In designing a locomotive cab, it is very advantageous to concentrate the heavy equipment between the center pins. A good rule is to have the radius of gyration with the cab swinging from one center pin, shorter than the distance between center pins.

In the running gear, it is desirable to have the radius of gyration measured from the center pin, less than half the wheel base. The closer the weight is concentrated to the center pin, the less tendency there is to nose and the easier the duty on the wheel flanges and track. The steam locomotive seldom has a good fore and aft distribution of weight, but its high center of gravity compensates for it.

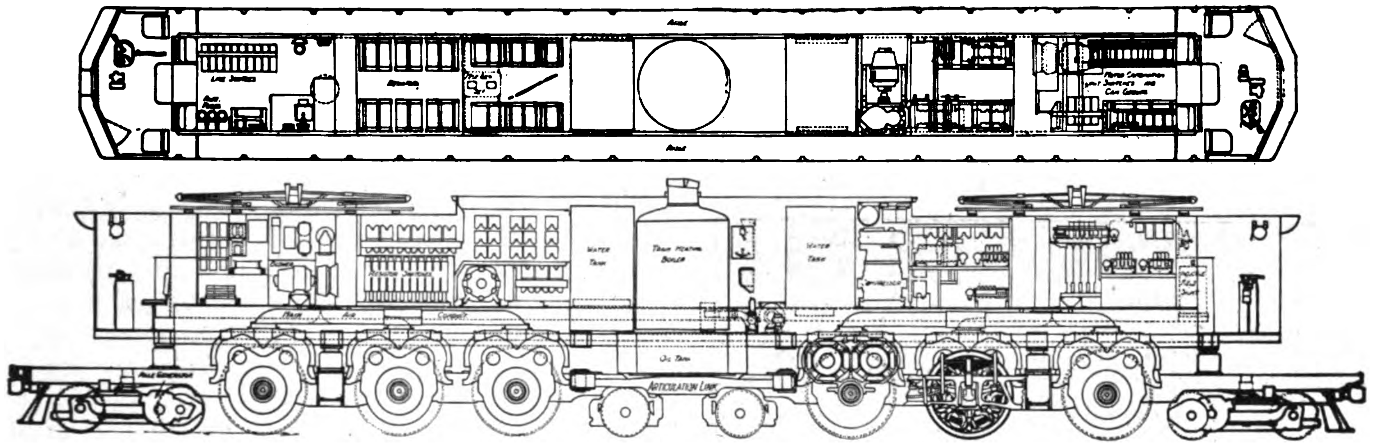

Fig. 15—Longitudinal Section of Locomotive

Mechanical Design. This locomotive has been designed to possess certain mechanical features which have developed through years of experience with steam locomotives. These characteristics are believed to be advantageous when applied to electric locomotive design as well. They may be summarized about as follows:

1. Distribution of weight, fore and aft, with respect to wheel base.
2. Height of center of gravity.
3. Length of rigid wheel base.
4. Guiding trucks.
5. Equalization.
6. Coupling between truck frames.
7. Diameter of driving wheels.
8. Non-spring-borne weight on driving axles, etc.

The principal means that contribute to good operation are:

1. The location of the mass of the locomotive as close to the center as possible.
2. High center of gravity of that portion of the locomotive carried on the running gear.
3. A long rigid wheel base to insure stability and also to decrease the transfer of weight due to drawbar pull.
4. Guiding trucks, located well outside the mass of the running gear, to contribute to stability, as well as leading the locomotive into curves.
5. Proper equalization to secure stability and weight distribution.

As concerns the size of drivers and dead weights,

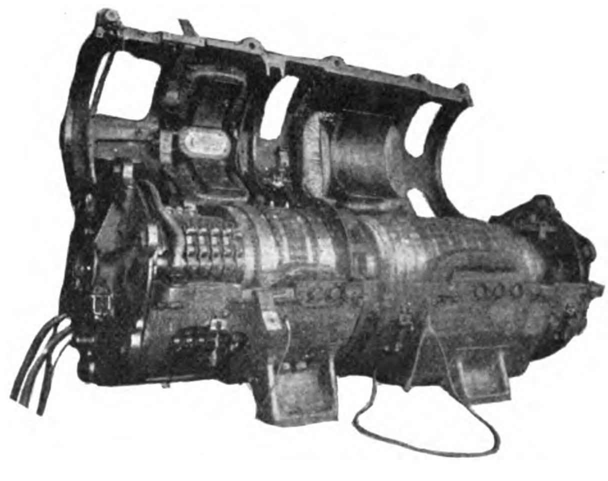

Fig. 16—3000-Volt-85-Volt Motor-Generator Set—Top Half Opened

it may in general be said that, other things being equal, the effect on track is inversely proportional to the square of the wheel diameter, and directly proportional to the dead weight.

This locomotive embodies all the foregoing features to a remarkable degree. Particular attention was given

to weight distribution. The cab has the boiler, water and oil tanks, storage batteries, air-compressor, resistors, motor-generator set, and the heavier parts of the control equipment, concentrated between the center pins. The driving motors are mounted above the axles on the running gear, thus getting the weight well inside the wheel base, but placing it relatively high. The height of the center of gravity of the complete locomotive is 68 in., a value that corresponds well with that of a steam locomotive.

The Pacific type of running gear with its long rigid wheel base and the guiding trucks is a particularly stable design and is especially good with the weight distribution that obtains on this locomotive. The height of the center of gravity of trucks with motors mounted is 43¾ in.

The quill drive, which is a further development of the one used on the New Haven locomotives, gives each driving axle perfect freedom to move vertically the full distance permitted by pedestal jaws without affecting the motors or frames, except through springs. The only "dead" weight carried is the weight of wheels, axles, journal boxes and spring clamps; a total of 7032 pounds for the wheels, axles and spring clamps which are rigidly fastened together, and 770 pounds for the journal boxes. This weight with the larger diameter of drivers (68 in.), and the total weight of 56,000 lb. per axle, gives a combination that is much better than has been considered very good practise on steam locomotives.

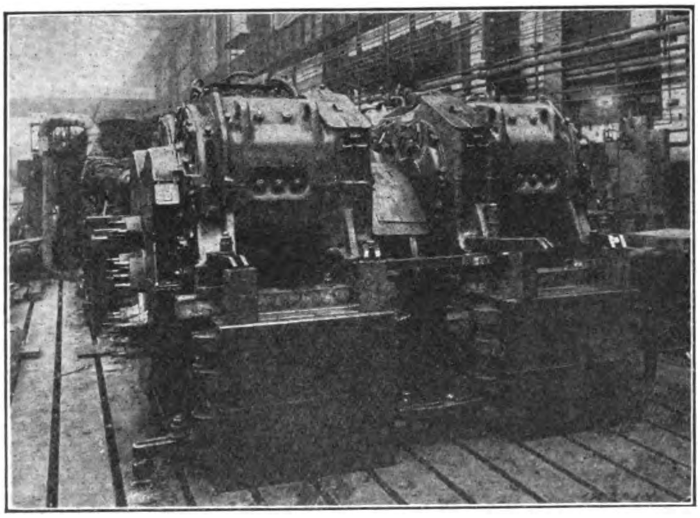

Fig. 17—Two 700-H. P. Motors Coupled Together for Test

Great effort has been made to cushion the locomotive against shock, either while running or from bumping. The apparatus in the cab is especially well protected since the cab rests on spring-supported plungers which are in series with the main semi-elliptic springs. The cab is protected against bumping strains by floating center pins, which, while held rigidly against lateral motion, are cushioned against longitudinal motion by heavy springs. It has been the practise heretofore with this general type of locomotive to have one center pin rigid in the running gear frame and allow the other one to move freely in a longitudinal direction. It is felt that it is much better to allow a slight relative motion between the two center pins, but to prevent the bumping shocks by spring cushioning.

Electrical Design

Main Motor. This was constructed of the twin armature type for several very good reasons:

1. The two armatures can both drive the same gear. A single armature motor would require twin gears, each of the same gear face as the present single gear in order to keep the tooth pressure down to the same value.

2. The space between wheels available for motors is limited and must be divided between gears and the motor itself.

The use of a second gear would take just that much space out of the armature core, and thus make a very large diameter necessary to get the output required.

3. A large diameter motor and double gears would increase the weight and cost of the locomotive.

4. A large diameter would make the motor extend farther up into the cab, thus necessitating raising the floor above the motors and cutting down the space available for other apparatus.

5. The use of two armatures makes it easy to design the motors so as to secure the advantages of low-voltage armatures for commutation.

6. Small armatures are easier to handle and cheaper to maintain than the large ones would be.

The capacity of the motor was fixed by the number of driving axles. Six driving axles were used as this seemed to be the smallest number that could be used with the limiting weight on the drivers. It was especially fortunate, as it led to the adoption of the double Pacific type of running gear with its excellent riding characteristics.

The characteristic curves of the motor, shown in Fig. 5 are taken from test; the efficiency being measured by the "input-output" method with all losses included. In making this test, two motors were connected together through gears, quills and quill springs; one motor being run as a motor, driving the other as a generator. See Fig. 17. The current from the generator was fed back through the motor by boosting its voltage, and the additional current required was supplied from an outside source. The measurements of the power supplied by the booster and from this outside source constitute the total losses in the two machines. The test was made on motors which had been operated only a few hours, consequently, the friction losses are probably higher than they would be after being in service for awhile; but the electrical and mechanical losses are thus included in the total, and the efficiency thus derived is the same as if the motors were on the locomotive. It is worthy of note that the efficiency

thus measured is materially higher than that calculated by the A. I. E. E. Rules from "no-load" losses and the fixed percentage of losses for gears and other load losses. These tests show plainly that those losses assumed for the Institute Rules are too high for large motors.

Fig. 4 shows the pinion end of the motor, and on the motor frame are shown the shields which protect the motor from melting snow falling into the outlet openings in the motor frame.

The motor armatures have very effective fans mounted on them which give the motors quite a high continuous rating without the use of any forced ventilation. It is expected that the blowers will not be used at all with normal train weight, except on heaviest grades.

Control. 1. The first thing necessary in designing the control for an electric locomotive is to decide on the combination of motors that is to be used.

2. To decide on the schematic arrangement of switches.

3. To decide on the necessary sequence of switches and arrange the master controller and suitable interlocks in the control circuit to insure following that sequence.

4. Calculate resistance values and the number of steps necessary to secure smooth control.

5. To design master controller, switches and other apparatus to meet these requirements.

6. To arrange overload trips so as to afford adequate protection from overloads and grounds in any part of the circuits, without producing dangerous voltage surges or serious arcing.

Where regeneration is to be provided for on a d-c. locomotive, it is essential,

1. To decide on a scheme that is inherently stable.

2. To arrange a schematic diagram of switches corresponding to the scheme, and to utilize as far as possible the same switches and sequence of switches as when motoring, so as to keep the total number of switches as low as possible.

3. To provide for beginning regeneration at any speed within the normal running range without having a heavy current in either direction that would produce a surge in the train.

4. To arrange the control so that the engine-man will have control of the regenerated power and speed at all times.

With six motors to drive the locomotive, some new problems were introduced.

The universal practise with d-c. motors heretofore has been to use the series-parallel arrangement, or at most, series, series-parallel and parallel, giving one-fourth, one-half and full speed. This scheme takes motors in multiples of two, or when two motors are connected permanently in series, in multiples of four.

With six motors and twelve armatures on 3000 volts, it would be possible to obtain the regular series-parallel control in several ways, had it been desirable.

1. A twin motor could have been wound for 3000 volts, and six motors then divided in three sets of two motors; each set being arranged for series-parallel.

With this arrangement, the motors would at least be less rugged and more liable to flashing than where they are wound for 1500 volts, and the control would be much more complicated.

2. The motors could be wound for 1000 volts each and connected permanently three in series.

This would give the simplest control; but connecting three motors on independent axles in series, would lead to dangerous over-speeding and two to three times the normal voltage on the motors in case of wheel slippage. It is common practise on high-voltage d-c. cars and locomotives to run with two motors permanently in series. The maximum voltage one can get in case of wheel slippage is less than double the normal voltage. This method has given very good results, but it is as high as it is safe to go with geared motors.

3. The motors could be wound for 2000 volts, that is, 1000 volts per armature, and three armatures connected permanently in series.

This would be open to the same objection from over-speeding and over-voltage on the motors whose armatures are in different circuits, and the motors would not be interchangeable, for some would have their armatures and fields connected in series inside the motors, and would thus have only four leads, while the others would have to have a separate set of leads for each armature and field winding.

In none of these three cases (except the second), would the control be materially simpler than the scheme that was finally adopted; but the best reason for the adoption of the one-third, two-thirds and full speed arrangement lies, not so much in any reasons that have been mentioned heretofore, as in the great advantage of the three-speed locomotive for handling the service. The one-third and the two-third speed arrangements cover the range so much better than the one-half speed, or than the one-quarter and one-half speeds, that there is scarcely any comparison possible. The half speed is too low for a running speed and too high for switching. The one-third speed is an excellent switching speed, and the two-thirds speed is a good running speed and is especially good for regenerating on heavy grades.

Another considerable advantage lies in the decreased rheostatic losses on this locomotive compared with one having the ordinary series-parallel control. The three speeds alone make a very considerable reduction in rheostatic losses; but when combined with the field shunting positions on each combination, reduce the rheostatic losses to less than one-half of what would be obtained with the ordinary series-parallel control. This, of course, means a very decided reduction in the weight of resistance necessary, as well as an increase in efficiency.

The combination of unit switches and cam switches gives a perfectly successful, and at the same time, the

lightest combination of switches possible. The unit switches are used in the high-voltage circuit wherever they are required to open the circuit with any current; thus the line switches, resistance switches and safety switches in the motor combination circuits are of the unit type and are interchangeable, except for interlocks which are easily transferred. The reverser switches, field shunt switches and those for regenerative change-over, exciter and auxiliary change-over are of the cam type, and operated by compressed air. These switches are assembled in groups of from four to sixteen switches; the sixteen-switch group being the reverser.

Shunt transition is used in passing from one motor combination to another as it is simple and gives sufficiently smooth transition to be very satisfactory. In changing from the first to the second combination, one-half of the motors are shunted momentarily; but in going from the second to the third speed, only one-third of the motors are shunted.

The sequence of switches is so simple that relatively few of the unit switches have interlocks on them, but the cam groups are all interlocked so that it is impossible to get false operation. The switches in any given cam group have the mechanical interlock provided by the cam shaft.

One of the fundamental principles on which this locomotive was designed was that the motor circuit should not be opened, either in normal operation or under emergency, until the current had been cut down by the introduction of resistance.

The specifications describe how this is done on this locomotive. It is considered to be a very valuable, if not an absolutely necessary, feature. It not only divides the arcs among a large number of switches and, therefore, promotes safety, but it prevents the generation of high voltages from suddenly rupturing a heavy current.

The line switches are located in a separate compartment from the resistance switches so that the four switches in series are always kept free for the final break.

Another fundamental principle in the regeneration was that the motors should never be connected to the line without the maximum starting resistance in series between motors and the line. This is a valuable provision in motoring, but is necessary in regeneration to prevent undesirable surges in the train.

This locomotive has approximately 17 ohms of resistance on the first step, consequently, the maximum current that could flow from the line would be less than 200 amperes, if there were no voltage generated in the motors at all. If this current is divided between two or three circuits, as would be the case on the second or the third combinations, the torque resulting, especially with the very small current in the motor field, would be negligible. The exciter rheostat is so arranged as to increase the voltage of the exciter immediately on closing the line switch until the flow of current through the resistance is practically zero, which means that the voltage of the motors equals that of the line. This method gives perfect safety in connecting the motor to the line and the stabilizing resistance and the axle-driven exciters add still more to the safety.

The stabilizing resistance protects the motors against sudden changes in line voltage, while the axle-generators protect against variations in grade, which would otherwise tend to vary the speed.

In case of a sudden reduction in line voltage, which would be followed by a heavy increase in the regenerated current, the increased voltage drop in the stabilizing resistance resulting from this, immediately cuts down the field current and generated voltage of the main motor sufficiently to limit the increase in regenerated current to a safe value.

In the case of the passage of a train from a sharp curve on a compensated grade to a tangent, there would be a tendency for a sudden heavy increase in speed, because of the steeper grade and the decrease in train resistance. As the speed increases, the voltage of the axle-generators automatically increases and, therefore, the field current of the main motors, which holds the train with a very slight increase in speed.

This scheme of regeneration offers a high efficiency as the only extra losses are those in the exciter and in the stabilizing resistance, both of which are small.

Auxiliaries. It has been the experience with high-voltage d-c. equipments that the auxiliary motors are very much more difficult to design than the main motors. More trouble is ordinarily experienced with auxiliaries than with the main current apparatus and in order to make such apparatus reliable, a great deal more expense is involved than would normally be warranted. It was the policy on this locomotive to limit the high voltage to the minimum possible number of circuits and the minimum amount of apparatus. It was impossible to avoid it altogether on the moving apparatus, due to the fact that the train lighting must be supplied for hours at a time in case of any emergency when the train is held up by a wreck or because of storms. The motor-generator set, which is designed primarily for this purpose, is the only piece of moving apparatus among the auxiliaries which has the high voltage applied to it. The voltage selected for the auxiliary circuits was primarily decided by the voltage required for train lighting. While 85 volts is lower than would otherwise be selected for the auxiliary motors, it is perfectly safe and is a voltage that is so low that the motors can be forgotten, as far as the questions of insulation and commutation are concerned. The auxiliary motors are, of course, very much smaller than would be the case, if the high voltage were applied to them.

A storage battery, from the standpoint of operation, is always a desirable thing on the locomotive as it

offers an opportunity for making a complete inspection of control apparatus by furnishing current for the lights and control, and for keeping up the air pressure without having the high-voltage current on the locomotive at all. Having a source of power to furnish light on the locomotive is a very desirable feature.

The combination of the storage battery and the axle-generators will furnish ample auxiliary power to take a locomotive to the end of a run, if the motor-generator set fails. The same combination will take a train safely down the longest and steepest grade with the air-brakes, if power is for any reason cut off the line. If the train is going up a grade and power is cut off, the battery will furnish air to hold the train with the brakes for a considerable time, so that it will not be necessary to block the wheels as is the ordinary practise, unless power is off for a considerable time.

Low-voltage motors are so small, comparatively speaking, that although there is a great difference in the power required for the compressor and the main blower motors, it was felt that the advantage of having the motors interchangeable was worthy of the increase in cost of the blower motors. The design of the compressor adopted is favorable to this, so that the motor is practically a standard industrial type of motor.

Thermostat. The thermostat, which is used for starting the blower motors, in accordance with the requirements, consists simply of a cast-iron resistance made up in tubular form, which is in series with the main motor armature. This resistance is enclosed by several micarta tubes so that it has substantially the same thermal characteristic as the main motor. There is a Sylphon tube contained within the resistance tube, which expands when a predetermined temperature is reached and closes the magnet circuit of the blower motor switch, thus starting the blower when that temperature is reached. The apparatus is very simple and rugged; and while, of course, it cannot follow the temperature of the motor absolutely, it is sufficiently accurate for the purpose.

Conclusion

The initial operation of these locomotives has given every reason to anticipate that good riding qualities, the advantage due to low-voltage auxiliaries, the flexible speed control, stability of regeneration, safeguards against short circuits, and the simplicity and ruggedness of the individual parts of the locomotive, form a combination that will be a great success in the service for which it was designed.

CLASSIFICATION FOR SUBJECTS IN RADIO SCIENCE

The radio laboratory of Bureau of Standards, Dept. of Commerce, has, in common with other workers in the radio field, felt the need for a systematic scheme of classification for subjects in radio science and engineering. This need is felt not only for use in classifying the references to current radio publications, but also for classifying other radio material such as drawings, books, miscellaneous reports, etc. The Bureau has made a step toward filling the need for such a classification by preparing an outline, the principal divisions of which are given following.

The entire subject of radio is divided into eleven classes, in addition to which are listed two classes which are related to radio. In the complete outline under each of these named classes are listed the divisions into which the material would seem to be logically divided. Undoubtedly, there are other divisions which it would be advisable to list and it may be that some of the headings given in this classification should be combined.

The Bureau desires to make this list as complete and comprehensive and especially as usable as possible, and would, therefore, appreciate any criticisms or comments. For complete outline or in submitting criticism, etc., address, Bureau of Standards, Dept. of Commerce, Washington, D.C.

Classification of Radio Subjects. A, Radio Wave Phenomena. B, Antennas. C, Electron Tubes. D, Radio Measurements. E, Properties of Materials. F, Radio Theory. G, Radio Research. H, Radio Instruction. I, Miscellaneous Radio Apparatus and Methods. J, Radio Communication and Applications. K, Radio Micsellaneous. L, Electrical Subjects Related to Radio. M, Miscellaneous.

NAVY APPROPRIATION BILL

Original estimates in this measure amounted to $573,131,254, which were pruned in committee to $425,289,574, and reported to the House March 18th. The bill carried a recommendation that the "Bureau of Steam Engineering" be changed to "Bureau of Engineering." It will have charge of all the Navy's electrical work as well as practically all classes of engineering work in connection with the use of steam. This Bureau is recommended for an appropriation of $28,000,000. The bill specifies among other things that the above amount is to be expended for "repairs, preservation and renewals of electric interior and exterior signal communications and all electrical appliances of whatsoever nature on board naval vessels except range finders, battle order, and range transmitters and indicators and motors and their controlling apparatus used to operate the machinery belonging to other bureaus; searchlights and fire-control equipments for anti-aircraft defense at shore stations; maintenance and the operation of coast signal service and instruments, apparatus, supplies, technical books, and periodicals necessary to carry on experimental and research work in radio telegraphy at the naval radio laboratory."

Passenger Locomotives for Chicago, Milwaukee & St. Paul Railway

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AND
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DECEMBER 9th, 1915, may be considered the date of the initial electrical operation over the electrified lines of the Chicago, Milwaukee & St. Paul Railroad. During the following winter the electrification was extended over 440 miles of route from Harlowton, Montana, to Avery, Idaho, a section which crossed the Belt Mts., the Rocky Mts., and the Bitter Roots. The locomotives for this initial electrification were of the geared type, designed and built especially with a view to the most economical operation of the freight service. The locomotives for passenger service differed from the freight locomotives only in the details where it was absolutely necessary to meet the operating requirements, such as changing the gear ratio to increase the speed and providing car heating and lighting equipment.

Three years later, in 1918, the successful operation of the original equipment had convinced the railroad company of the economical advantages of electric operation, and they decided to equip an additional section extending over the Cascade Mts. between Othello, Washington, and Tacoma, Washington, a distance of 212 miles. In choosing the equipment for the new extension, it was decided to give special emphasis to the requirements of passenger service and to purchase locomotives which were primarily designed with this in view, taking advantage of any details which would assist in the proper and economical operation of passenger trains. For the freight service it was decided to retain the geared locomotives that were in use on the Harlowton-Avery Division, changing the gear ratio where necessary to meet freight conditions, and using only locomotives of the new design for passenger service.

To meet the specification for passenger locomotives, the General Electric Company has designed, completed, and tested, a locomotive which appears to embody the necessary qualifications and to successfully fulfill the requirements, both from electrical and mechanical standpoints. In designing the locomotive, particular attention has been given to the features affecting safety, reliability, efficiency, convenience of operation, effect on track, and cost of maintenance. The locomotive has especially good riding qualities; it has no apparent effect on the alignment of the track, and to a marked degree, it is free from transverse movements or oscillation which would tend to create lateral pressures against the rails.

Presented at the Pittsburgh meeting of the A. I. E. E., March 12, 1920.

It is the intention of this paper to give a description of this locomotive which differs in many ways from the locomotives which are now in operation on the Harlowton-Avery Division, to indicate the reason for choosing this design, and to call attention to some of the principal features which differ from usual practise. Briefly stated, the service requirements for the locomotive are to operate a 950-ton passenger train over the mountain divisions of the Chicago, Milwaukee & St. Paul Railway at speeds of 25 mi. per hr. up 2 per cent grades with maximum operating speeds of 60 mi. per hr. on the level, and to provide regenerative braking on the down grades at speeds consistent with safe operation. Fig. 1 is a photograph of the locomotive in three-quarter view. Fig. 2 is an outline drawing of the side elevation, giving the general dimensions. Fig. 3 is a section through the apparatus cab, showing the location and arrangement of the principal pieces of apparatus.

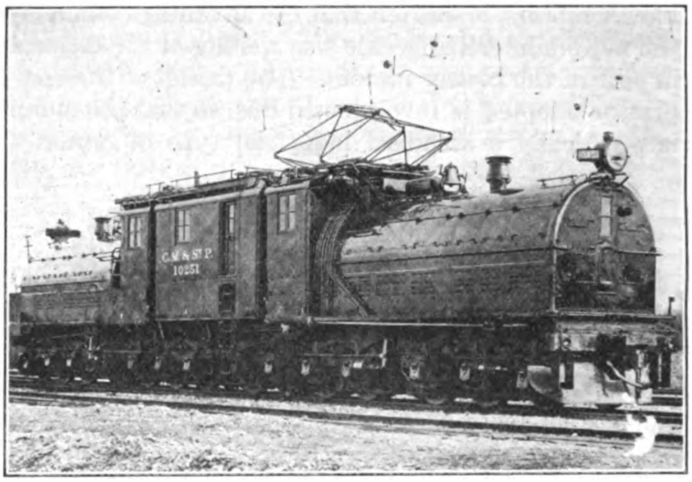

FIG. 1—THREE-QUARTER VIEW OF LOCOMOTIVE

It will be seen that the running gear is composed of four individual trucks; two end trucks having three axles each, and two center trucks having four axles each. These trucks are connected together by special articulation joints. The motor armatures are mounted on the axles and the motor fields are carried on the truck frames.

The superstructure is made in two sections of similar design with a third section between them. The third or central section contains the train heating equipment, which consists of an oil fired steam generator, together with water and oil tanks. This unit is complete in itself, and is carried over supports attached to the two

middle trucks. It can be readily removed for repairs without interfering with any other part of the locomotive. It is placed between the two operating cabs in order to be easy of access to the engineer's helper or fireman, from either location.

The two end sections are similar to each other in appearance. The operator's cab in either section is on the inner end next to the heater cab above described, in order that the operator can be convenient to the heater and in order to allow a maximum space for apparatus in the apparatus cab or outer end section. Another advantage of this arrangement of cabs is that the operator can have access to any section of the locomotive requiring his presence without passing through a section containing high-tension apparatus. The engineer's or operating cab contains a main or master controller, the air brake valves and handles, and an instrument panel, containing air gages, ammeters, and speed indicator. The engineer uses either of the two operating cabs according to the direction in which he is running.

A door gives access from the operating cab to the apparatus section which extends with a cylindrical top to the extreme end of the locomotive. The cylindrical construction naturally adapts itself to the protection of the apparatus included and in addition to this, it has the advantage of allowing a clear vision for the operator from his normal operating position. Contained in this apparatus section are the resistors and contactors to control the power circuits of the locomotive. The starting resistors are placed in two rows on each side of the central passage just above the floor of the superstructure and are covered at the sides by removable covers which when opened will allow the separate resistor boxes to be slid out upon the longitudinal running board outside of the apparatus cab. The air compressor for the air brakes, the motor-generator set for train lighting, and the storage battery for marker lights and emergency control, stand upon the same level as the resistors, and can be removed or replaced in a similar manner. Above the resistors are located the contactors with their arc chutes facing a central aisle two feet wide. This allows ample arcing space and room for inspection of contactors. Above the contactors is the cylindrical roof of the locomotive with trap doors for inspection of the back connections and insulation and for removing the contactors in case replacement is necessary. The whole design and arrangement of this apparatus cab lends itself to a maximum economy of cost and material, as well as to convenience of inspection and repair of apparatus.

Motors

The motors are of the well known bi-polar gearless design which were adopted by the New York Central Railroad 14 years ago, and which have proved by fourteen years' service, operating heavy passenger trains between Grand Central Station and Harmon, to be well suited for the service. This motor has demonstrated its remarkable reliability and low cost of maintenance.

To insure light weight per axle, flexibility in control, good truck arrangement for curving as well as for high-speed running, twelve motors are chosen, each of relatively small capacity. They are especially designed to withstand high temperature, being insulated with mica and asbestos.

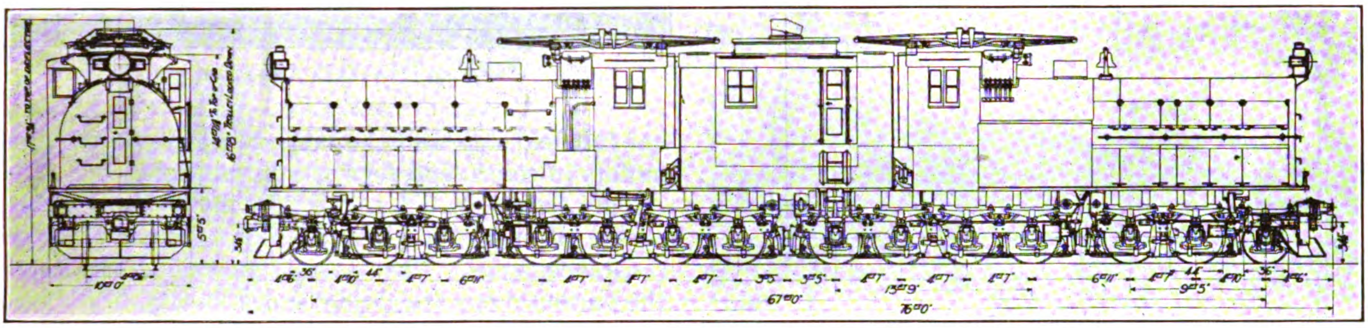

Fig. 2—Outline Drawing and Dimensions of Locomotive

Fig. 4 shows the motor armature complete, built directly on the axle with the wheels pressed and keyed in place. The continuous rating of each motor at 1000 volts and with 120 degrees rise by resistance is 266 h.p., corresponding to 3500 lb. tractive effort at the rim of the drivers at a speed of 28.4 mi. per hr. Forced ventilation is employed for cooling. The armature core is provided with holes for the passage of ventilating air. Ventilating blowers are located above each motor armature and deliver air at the commutator end of the motor where it divides, a part passing through the armature and a part back through and around the field coils where it escapes upwards and is afterwards used for ventilating the starting resistors.

This type of motor gives very high power efficiency in average operation, it having no journal bearings or gearing. It lends itself nicely to simple and compact locomotive design as the frame is made use of to furnish the entire path for the magnetic flux. The pole pieces and field coils are fastened to the cross transoms of the trucks and the magnetic flux passes horizontally in series through all twelve motors, finding a return path through the locomotive frame. The articulation joints between the trucks are made in such a manner that large surfaces are in contact to provide an easy

path for the flux. The pole pieces are made flat in order to prevent the pole pieces from coming in contact with the armature during the vertical movement of the truck frame on its springs or when removing or assembling the armatures. A minimum clearance of ⅛ in. on each side is allowed between the armature and the pole piece tips. The brushholders are bolted to the transom allowing the brushes to move up and down with the fields as the frame rides on the truck springs.

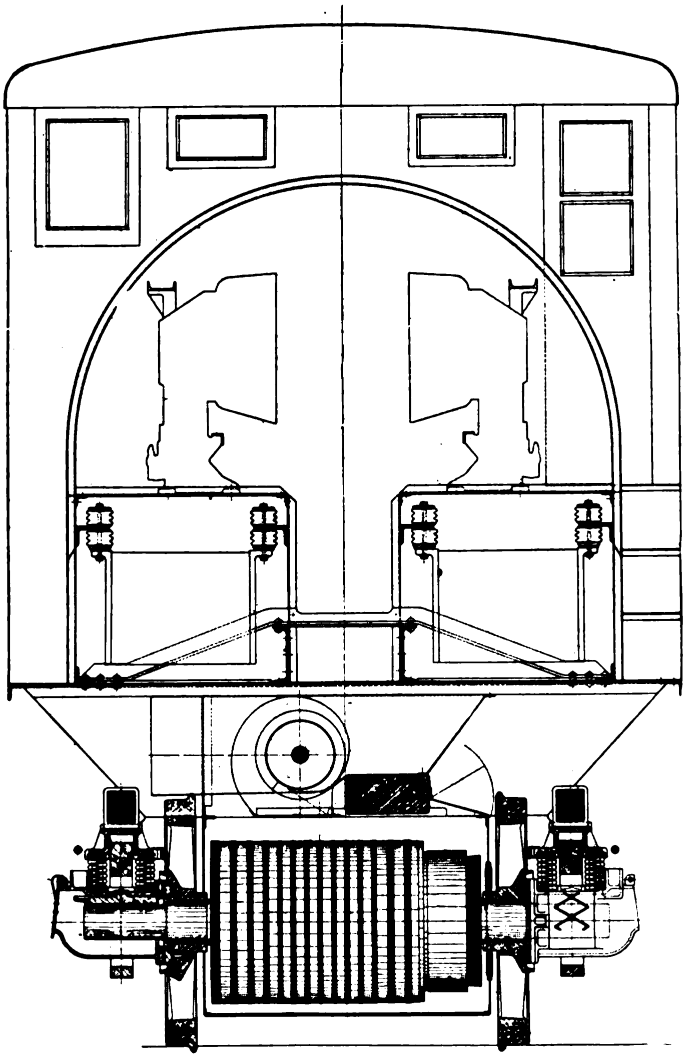

FIG. 3—CROSS-SECTION OF APPARATUS CAB

CONTROL

In choosing the control apparatus special care has been taken to use individual pieces of apparatus best suited to the particular requirements. Where single independently operating switches are necessary as on the resistance notches, electro-magnetic control is used. Where several switches are required to operate at one time as in changing from series to parallel motor connections, banks of switches with electro-pneumatic cam control are used, thus insuring positive operation, eliminating interlocks, and simplifying the wiring.

The control for motoring is arranged for four motor combinations.

The first combination has nine rheostatic steps, one full field step, and one tapped field step, with twelve motors in series across 3000 volts.

The second combination has six rheostatic steps, one full field step, and one tapped field step, with six motors in series and two sets in multiple.

The third combination has eight rheostatic steps, one full field step, and one tapped field step, with four motors in series, and three sets in multiple.

The fourth combination has eight rheostatic steps,

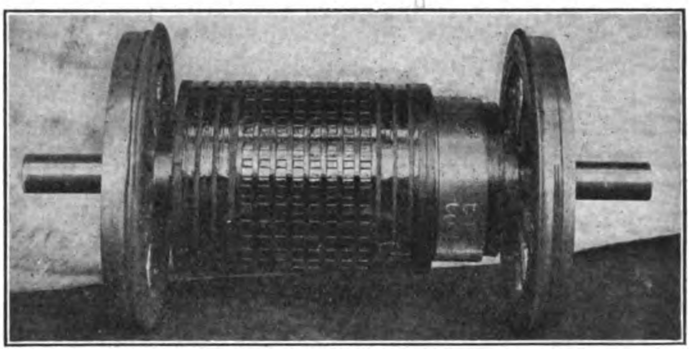

FIG. 4—BI-POLAR GEARLESS ARMATURE AND WHEELS

one full field step, and one tapped field step, with three motors in series, and four sets in multiple.

This results in a total of 39 control steps with a choice of eight operating speeds, exclusive of the resistance steps. The locomotive characteristics on the various steps are clearly shown in Fig. 5.

The regeneration of power for braking is accom-

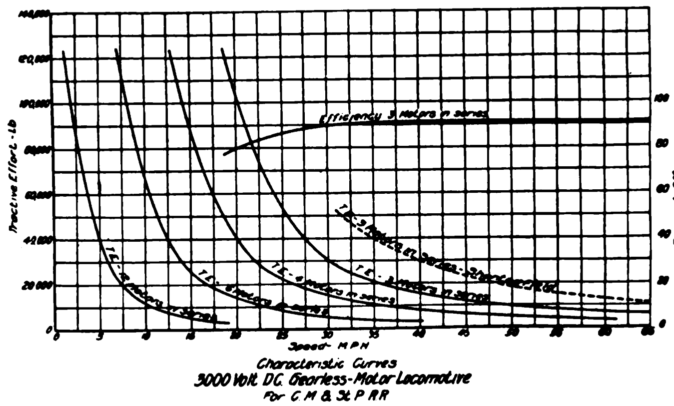

FIG. 5

plished in a simple manner by using some of the motors for exciting the fields of the others, which in turn are used as generators to return power to the line.

As a provision against short circuits, or extreme overloads, a quick acting circuit breaker is provided in the apparatus cab which will protect the circuit in less than 1/100 of a second.

MECHANICAL CONSTRUCTION

For flexibility in curving, the running gear is made up of four trucks, each of a relatively short wheel

base. The two middle trucks have four driving axles each; and the two end trucks, two driving axles and one guiding axle each, making a total of 14 axles. The trucks are connected together with articulated joints which allow of no relative lateral movement between them, so that each truck positively leads the following truck. This is for the purpose of reducing flange wear on curves and lateral oscillation on tangent track.

The most important problem that has to be faced in the design of a locomotive for high-speed passenger service is the problem of limiting as far as possible the lateral oscillations of the locomotive structure which tend to distort the track, and to minimize the effect on the track of such oscillations as occur. If a locomotive were built with a rigid wheel base as long as the total wheel base of the present locomotive (67 ft.), the lateral oscillations could not reach any large angular value. However, on account of the long wheel base, such a locomotive would be incapable of taking curves. By articulating the wheel base, as we have done, the locomotive is capable of accommodating itself to track curvature,

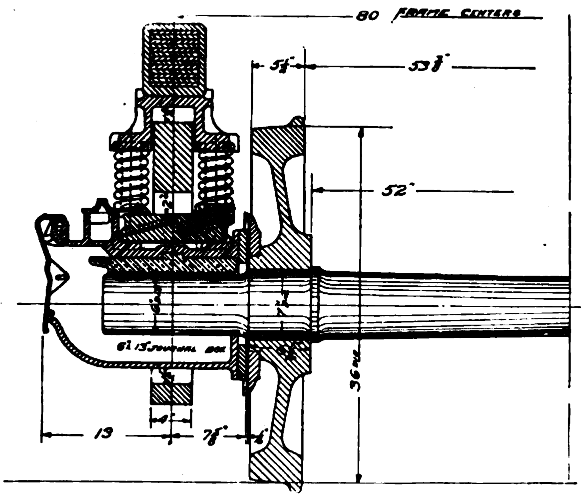

Fig. 6

but at the same time, on account of the articulation between trucks, and the consequent guiding effect of one truck on another, the lateral oscillations on tangent track are minimized in the same manner as would be done by the use of a long rigid wheel base.

To soften any lateral blow that may be given against the rail, the leading and trailing axles are allowed a movement of one-half inch relative to the truck frame, either way from their central position. This movement takes place against a resistance introduced by wedges above the journal boxes which tend to hold the box in its central position and to give a dead beat action opposing the motion. This wedge construction is illustrated in Fig. 6. To further protect the track from lateral displacement on the ties, the outer end of the superstructure is carried on rollers, bearing on inclined planes upon the truck frames, while the inner end of the superstructure is rigidly fastened to one of the middle trucks. This construction tends to hold the leading and trailing trucks in their central position. When a blow is delivered by the leading or trailing truck against the rail head, the superstructure, is displaced laterally across the outer truck. In such a sideways displacement, the weight of the superstructure rolls up on the inclined plane on that side, and thus transfers weight to the rail that is affected and increases the adhesion of the rail to the tie. This action really has two results. It not only increases the holding power between rail and tie at that point, but it introduces a time lag and increases the time and distance during which the pressure is delivered to the rail head.

As a matter of record, it should be said that the first of these new locomotives was delivered to the railway company at Deer Lodge, Montana, on December 14th, 1919, and was put in operation handling passenger trains between Deer Lodge and Avery.

For convenience of reference a table is attached giving a summary of the principal dimensions and characteristics of this locomotive.

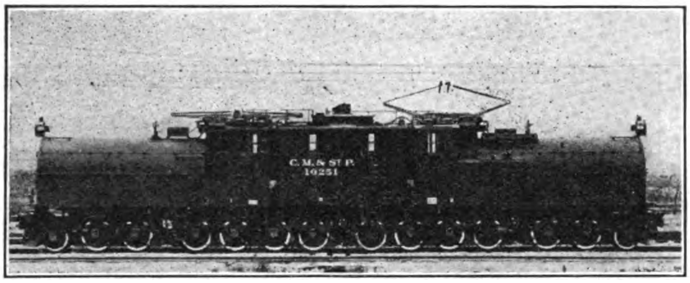

Fig. 7—Side View of Complete Locomotive

Total weight	521,200 lb.		
Total weight on drivers	457,680		
Weight per driving axle	38,140		
Dead weight per driving axle	9,590		
Weight per idle axle	31,750		
Dead weight per idle axle	3,560		
Length overall	76 ft.	0	in.
Width overall	10 ft.	0	in.
Height over cabs	14 ft.	11⅝	in.
Height over pantograph, locked down	16 ft.	8	in.
Total wheel base	67 ft.	0	in.
Max. rigid wheel base	13 ft.	9	in.
Diameter of driving wheels	44 in.		
Diameter of idle wheels	36 in.		
Size of journals	6 in. by 13 in.		
Dimensions of operator's cab	5 ft. by 10 ft.		
Dimension of heater cab	14 ft. 11 in. by 10 ft.		
Heater capacity	4,000 lb. steam per hr.		
Water capacity	30,000 lb.		
Oil capacity	6,000 lb.		
Compressor capacity	150 cu. ft. per min.		
Number of motors	12		
Type of motor	(bi-polar) GE—100		
Diameter of armature	29 in.		
Clearance between bottom plate and top of rail	5¼ in.		
Working range of pantograph	9 ft.	0 in.	
Locomotive Rating	*Tapped field*	*Full field*	
Total horsepower, 1 hr. motor rating	3,480	3,380	
Total tractive effort 1 hr. motor rating	36,000	46,000	
Speed mi. per hr	36.2	27.5	
Total horsepower continuous	3,200	3,200	
Total tractive effort continuous	32,000	42,000	
Speed, mi. per hr	37.8	28.4	

Flashing of 60-Cycle Synchronous Converters and Some Suggested Remedies

BY MARVIN W. SMITH

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WITH the increasing application of 60-cycle synchronous converters to railway service, the question of flashing is receiving considerable attention. A series of tests has recently been made, and others are still in progress, with a view to determining the possibilities of protection from flashing by various methods, including the "quick-acting breaker," "flash suppressor," "flash guards" and various modifications and combinations of these. The converter that has been used for these tests is a standard 500-kw., 600-volt, six-phase, 60-cycle, 1200-rev. per min. machine. It was supplied with power from a 5000-kv-a. generator through three standard high-reactance transformers. These transformers had a reactance of approximately 17 per cent at normal load and 10 per cent on short circuit.

An interesting and rather surprising feature shown by the tests is the extremely rapid rate of increase of the direct current on short circuit as compared with direct-current generators. For example, tests made on the generators of the 2000-kw. sets for the Chicago, Milwaukee and St. Paul Railroad, show the initial rate of increase in current on short circuit to be approximately 1,100,000 amperes, or 1650 times full load, per second. Also short-circuit tests on a 1000-kw. 600-volt direct-current generator show an initial rate of increase in current of approximately 2,700,000 amperes, or 1620 times full load, per second. On the 500-kw. converter, however, the average initial rate of increase is approximately 3,300,000 amperes, or 4000 times full-load current per second. This large difference between the rates of increase of short-circuit current for the d-c. generators and the converter cannot be accounted for by the difference in the inductances of the machines. In fact, the calculated inductances of the generators, which are of considerable lower frequency than the converter, are lower than the calculated inductance of the converter. The difference may be due to the fact that the alternating current which is a motor current building up in the opposite direction from the direct current, produces, or tends to produce flux linkages in the armature winding which oppose those of the direct current, with the result that the induced voltage opposing the rise of direct current is reduced. In other words, a higher rate of increase in current is necessary to produce the required counter voltage, which accounts for the higher rate of increase in current in a synchronous converter than in a direct-current generator. Reference to oscillogram Fig. 1 shows that the current reaches its maximum value in approximately 0.006 seconds. This rapid increase in short-circuit current together

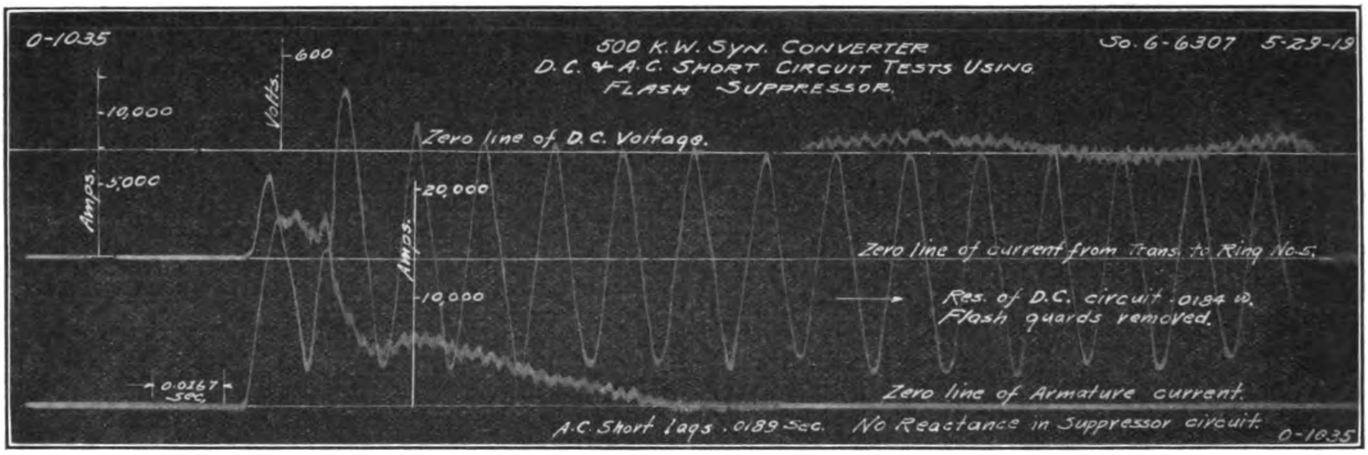


FIG. 1

Reasons why 60-cycle converters are susceptible to flashing. The protection of the 60-cycle converter is more difficult than the protection of any other class of commutating machines due to the inherent limitations of distance between neutral points on the commutator. The limiting distance between neutral points is fixed by the frequency and peripheral speed of the commutator. For instance, considering the maximum allowable peripheral speed as 5500 feet per minute, the distance between neutral points in the case of a 60-cycle machine will be approximately 9.2 inches regardless of the speed or number of poles. This may be readily seen from the following simple relation:

$$\text{Dist. between neut. points} = \frac{\text{circum. com.}}{\text{poles}}$$

$$= \frac{\text{periph. speed}}{\text{rev. per min.} \times \text{poles}} = \frac{\text{periph. speed} \times \text{poles}}{\text{poles} \times 120 \times \text{freq.}}$$

$$= \frac{\text{periph. speed}}{120 \times \text{freq.}}$$

Presented at the Pittsburgh Meeting of the A. I. E. E., March 12, 1920.

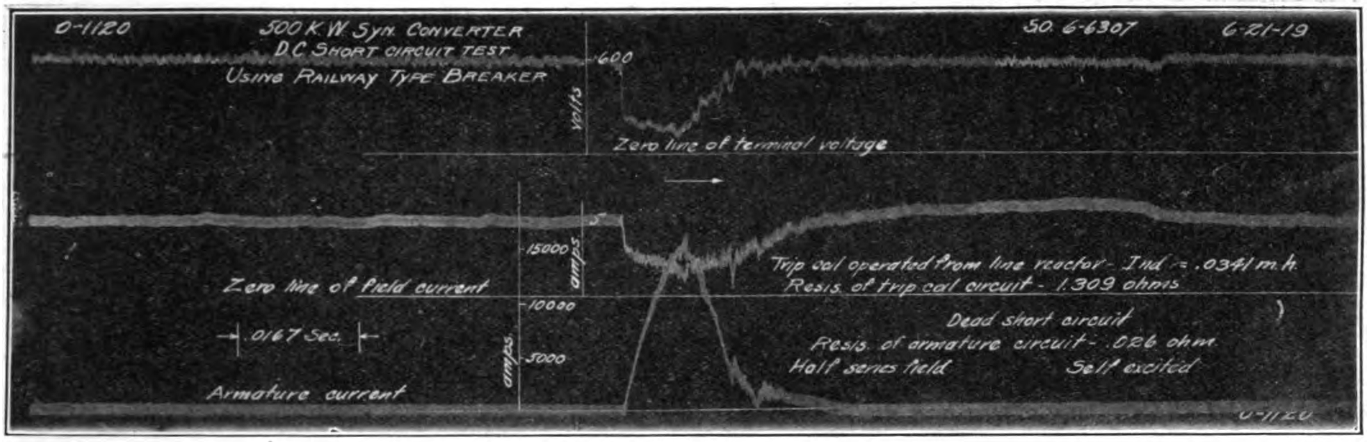


Fig. 2

with the limited distance between brush-holder arms, makes the 60-cycle converter particularly susceptible to flashing trouble.

Conditions Causing Flashing

Flashing does not appear to be entirely dependent upon the point or value at which the current is arrested. Oscillograms in Figs. 2 and 3 show dead short circuits on the machine when protected by a modified high-speed railway-type breaker. The current was limited to approximately 14,500 amperes, 17½ times full load, the rate of current increase being limited to some extent by the use of a small reactor as a shunt for the trip circuit of the breaker. (The maximum short-circuit current value of this machine is approximately 19,000 amperes or about 23 times full load). However, at this speed the machine was completely protected, except for slight pitting of the brush holders, even at this high current value. The voltage records show clearly that the machine cleared itself immediately after the complete opening of the breaker, which took place in approximately 0.015 seconds. Fig. 4 shows an overload only one-fifth the above value in connection with the ordinary low-speed breaker, from which it is evident that the machine bucked over immediately after the breaker opened even at this lower value of current. When a machine is on short circuit a large percentage of the voltage is consumed internally. The heavier the short circuit the larger is the percentage of the voltage thus consumed. Then so long as the d-c. breaker is closed the voltage between brush arms and hence the tendency to flash is a minimum. The voltage between neutral points on extreme overload and short circuit with the d-c. breaker closed, is also dependent somewhat upon the brush pressure. The higher the brush pressure the lower the contact drop and hence the external voltage between neutral points. This contact drop may be quite appreciable if the brush pressure is low enough to allow the force of the arc to lift the brushes off the commutator, which means a lower percentage of the voltage will be consumed internally, with a result that the voltage on the commutator will be higher. Assuming a reasonable brush pressure and contact drop, it is practically impossible for a machine to buck over and hang on between arms on dead short circuit so long as the d-c. breaker is closed, for the voltage on the commutator is practically killed just in the same manner as in the case of the flash suppressor referred to later. It is usually the opening of the d-c. breaker that does the damage. Tests in connection with both the low-speed and high-speed breakers and, in fact, ordinary operating experience show that a machine rarely bucks over until the d-c. breaker opens. See Figs. 4, 5 and 6. There

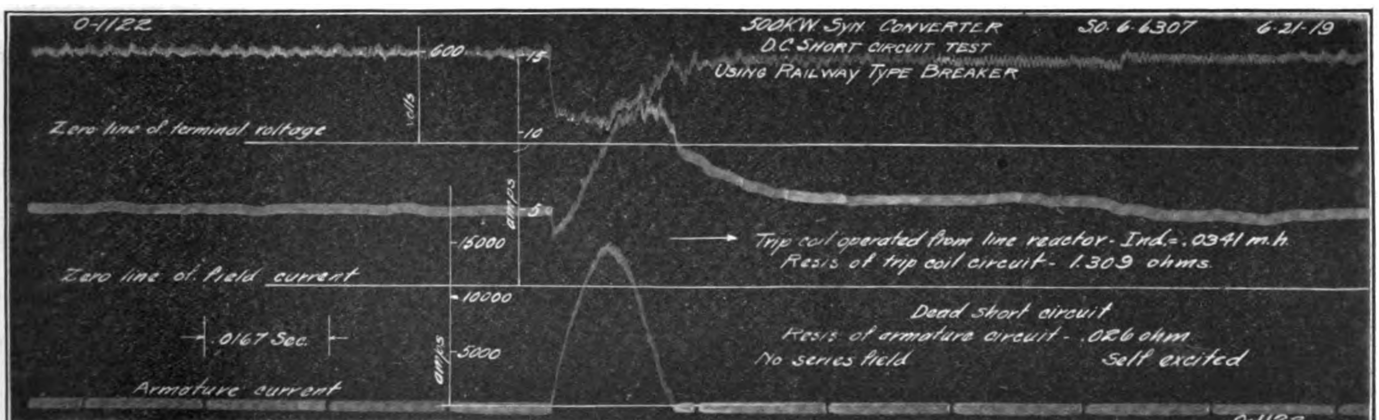


Fig. 3

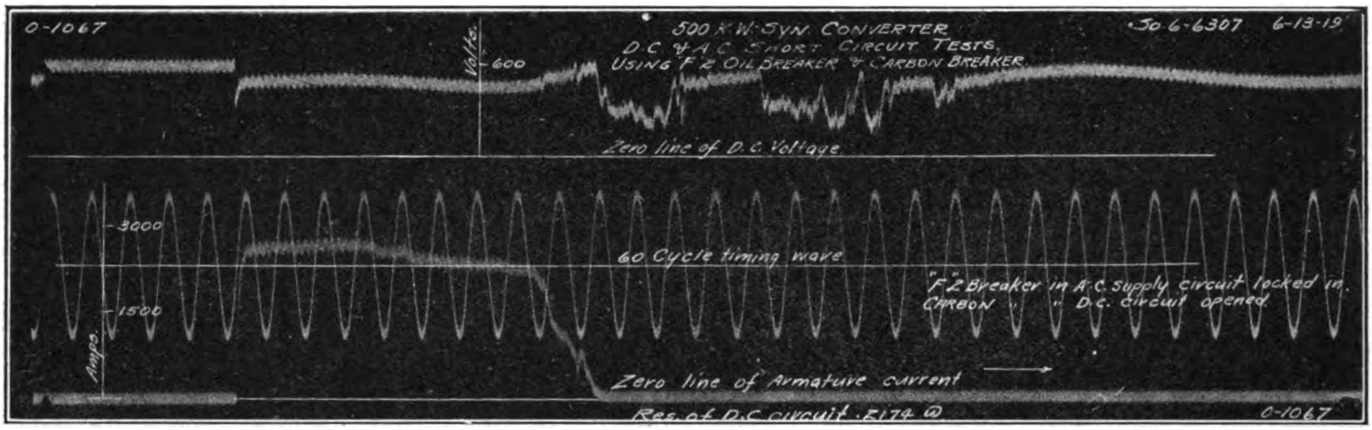


Fig. 4

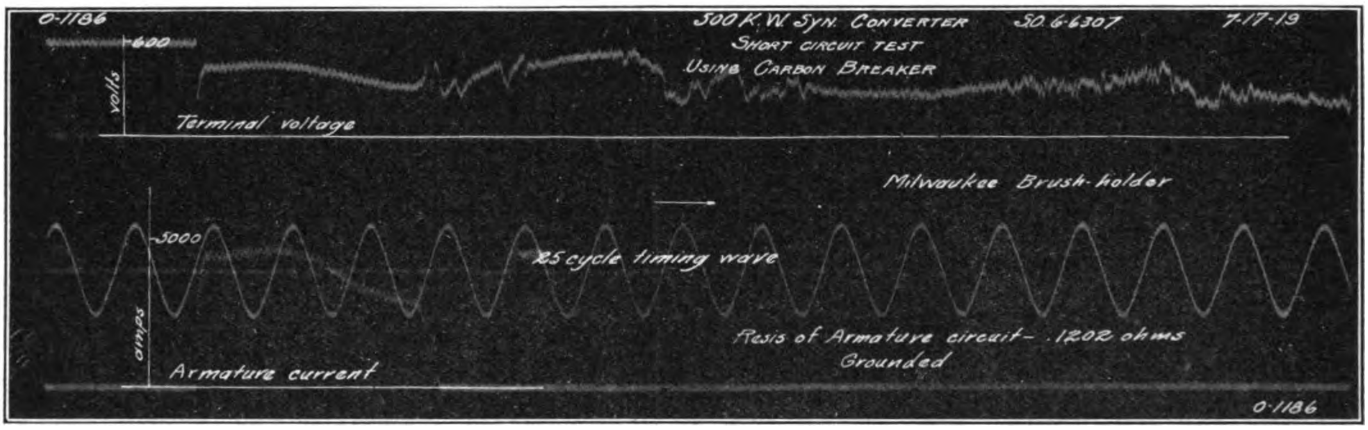


Fig. 5

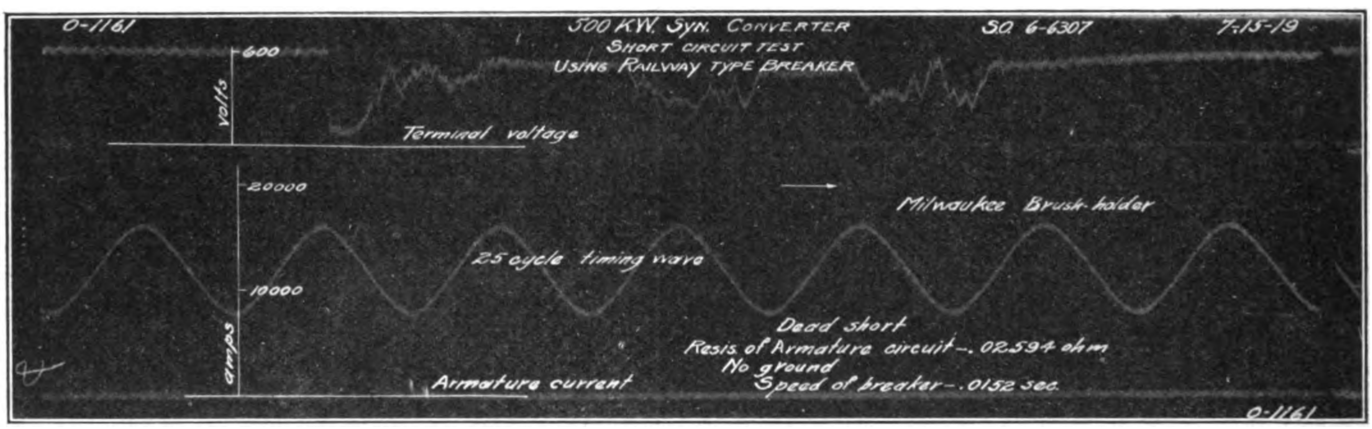


Fig. 6

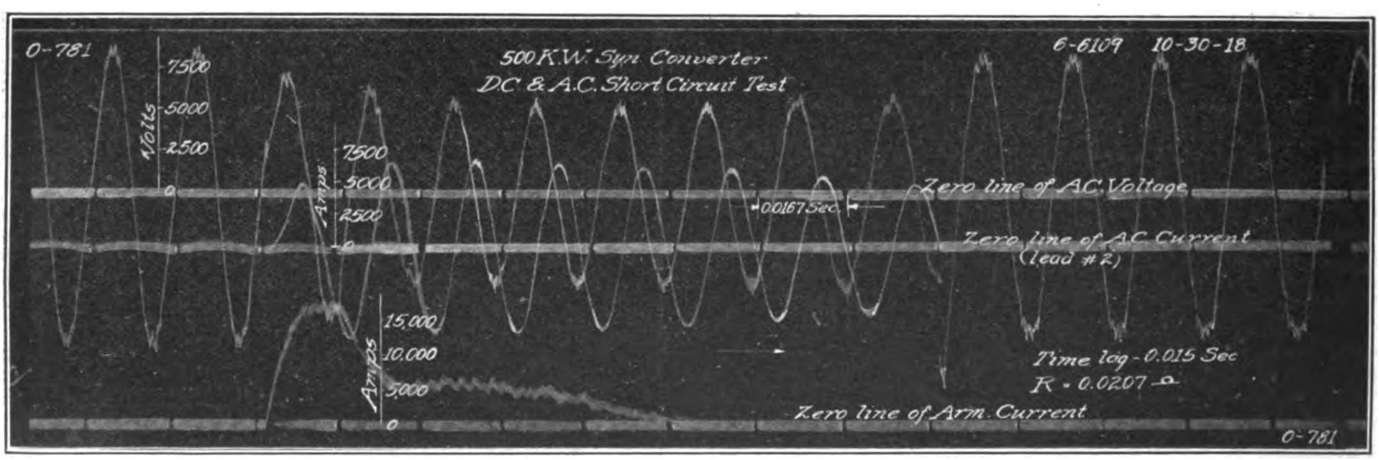


Fig. 7

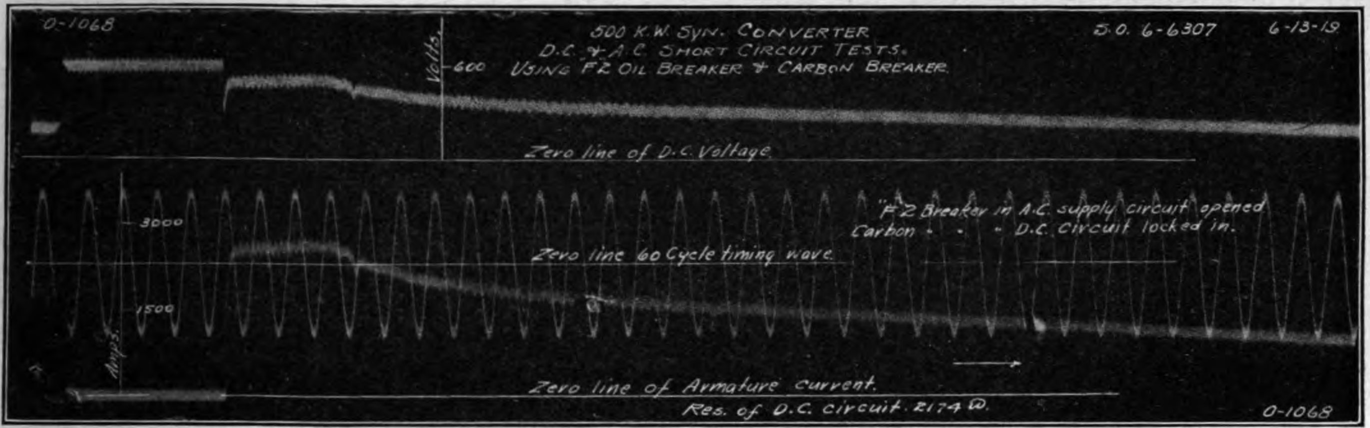


FIG. 8

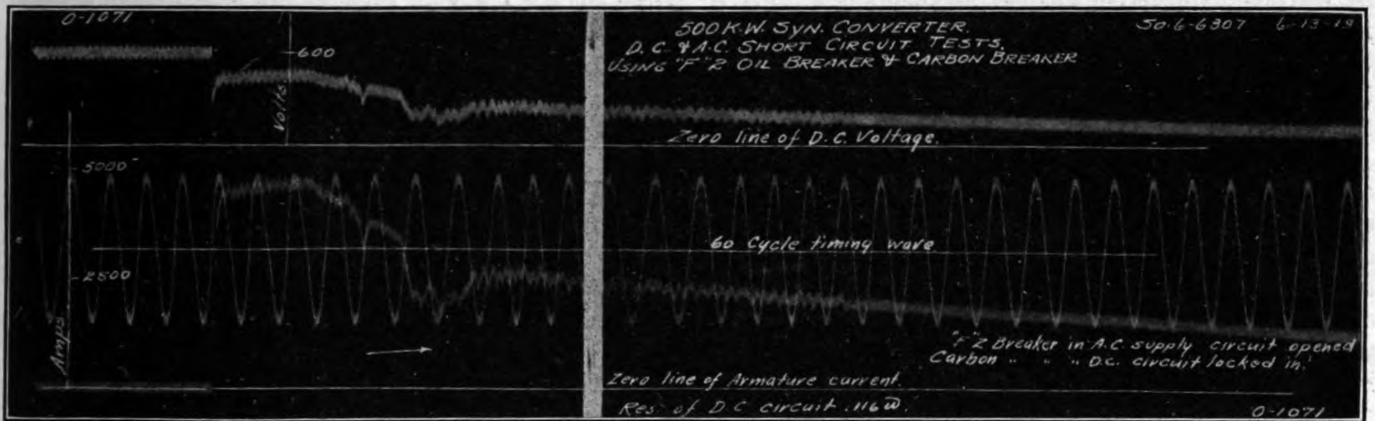


FIG. 9

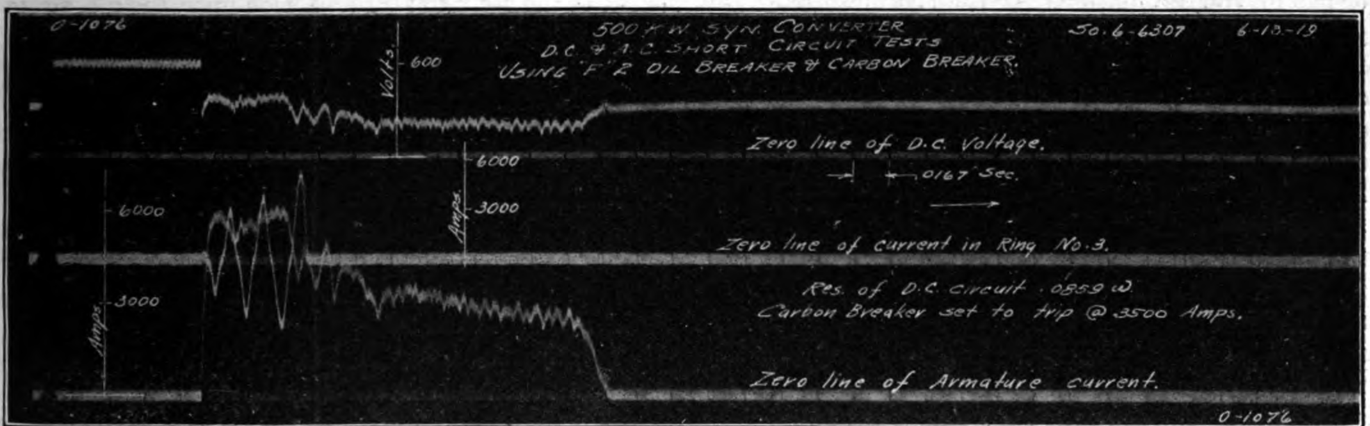


FIG. 10

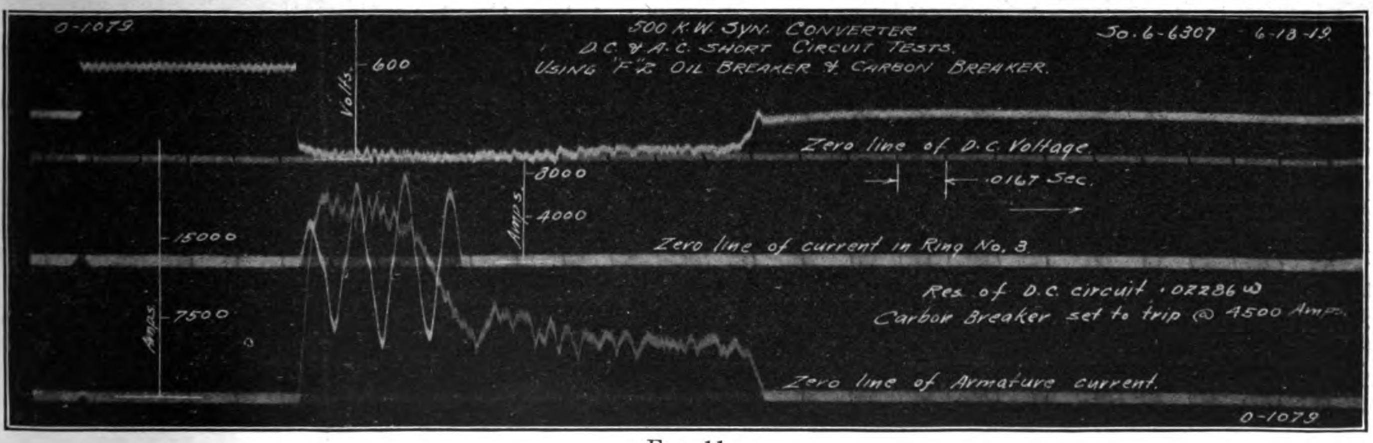


FIG. 11

may be considerable flame on the commutator due to the heavy current, but it does not have the tenacity nor power to cause any serious damage until the voltage is restored. Figs. 1 and 7 covering oscillograms taken in connection with the flash suppressor in which approximately one cycle elapsed between the time of the d-c. short circuit and the application of the a-c. short circuit, show clearly that the machine did not buck over before the a-c. short circuit was applied. During this time the commutator rotated through a distance corresponding to two neutral points. Figs. 8 and 9 show overloads of 3 and 6 times full load respectively when the d-c. breaker was tied in and did not open at all. However, the d-c. supply was tripped off about 0.06 seconds after the instant of short circuit as shown by the slight dip in the current and voltage wave. It is evident from the steady nature of the voltage wave that the machine did not buck over and hang on between arms, although there was considerable flash on the commutator.

Therefore, the ideal circuit breaker is not necessarily one which opens the circuit before the machine bucks over (for it usually does not buck over until the breaker opens) or before the current reaches a certain value, but one which opens the circuit before sufficient gas and volatile matter has been formed over the commutator to cause the machine to buck over when the voltage is restored by the opening of the breaker. It may be said that flashing is roughly a function of the voltage and distance between neutral points and the amount of gas or volatile matter over the commutator. This gas is again dependent upon several other variables, such as, the inherent commutating characteristics of the machine (which is a measure of the local short-circuit currents under the brush), the value of the load current and the time it has been flowing, the grade of brush, etc.

It is the writer's opinion in view of the above tests that a moderately high-speed breaker is no better than an ordinary slow-speed breaker. In the case of a moderately high-speed breaker probably as much gas as possible has been formed over the commutator by the time the breaker opens, *i. e.* after this point the gas is dissipated as fast as it is generated. Then a very slow-speed breaker may be even better than a moderately high-speed breaker due to the fact that the voltage will have time to die down appreciably before the breaker opens, especially, if the a-c. supply is opened in the meantime.

Opening the a-c. breaker is of course undesirable because the machine has to be synchronized again. However, this procedure minimizes the flashing considerably. Figs. 10 and 11 cover an overload of approximately seven times full load and a dead short circuit respectively taken under this condition. As shown by the a-c. wave, the a-c. supply was tripped off approximately 0.05 seconds after the instant of the d-c. short circuit. The opening of the d-c. breaker was purposely delayed as long as possible (by changing spring adjustments) so as to allow time for the current and voltage to die down due to the decreasing speed as well as the dying down of the field flux. In the case of the dead short circuit it may be seen that the current has dropped to almost one-fourth of the maximum short-circuit value and the voltage has dropped to less than one-half normal value when the d-c. breaker opens. The machine immediately clears itself upon the opening of the d-c. breaker as shown by the voltage record. During the period prior to the opening of the d-c. breaker there was of course considerable flame on the commutator but due to the limited voltage on the commutator (with the d-c. breaker closed) the arc did not have the tenacity to hang on, and by the time the d-c. breaker opened the current and voltage had reduced to such an extent that the arc could not establish itself.

Influence of Commutating Characteristics on Flashing

Oscillograms covered by Figs. 12 and 13 which were taken at lighter loads and where the a-c. supply was cut off prior to the opening of the d-c. breakers, show clearly by the dip in the current and voltage wave that the machine bucked over slightly before the d-c. breaker opened, which appears contrary to previous conclusions. However, at this light load the voltage on the commutator is not appreciably reduced. Furthermore, with the a-c. supply cut off, the neutralizing effect of the a-c. armature reaction upon the d-c. armature reaction is absent. Therefore, the converter, operating as a straight d-c. generator with the increased effect of the armature reaction upon the commutating-pole circuit, is erroneously under-compensated, with the result that the sparking under the brush is greatly increased which together with the high voltage between neutral points causes the machine to flash over even with the d-c. breaker closed. This again emphasizes the importance of the inherent commutating characteristics of the machine.

The relative strength of armature and commutating-pole fields has a considerable influence upon the commutation and hence upon the flashing of a synchronous converter on sudden changes of load and extreme overload or short circuit. Under normal load conditions the a-c. m. m. f. opposes the d-c. m. m. f. In the interpolar space the resultant armature reaction is only about 15 per cent of the d-c. armature reaction, and is in the same direction as the d-c. reaction. The commutating-pole field ampere-turns under this condition are just sufficient to buck down this resultant m. m. f. and in addition to force sufficient flux across the commutating-pole gap to generate the required counter voltage for commutation. However, at the instant of short circuit the converter acts largely as a d-c. generator delivering the first rush of current from its own inertia, with the result that the machine is enormously under-

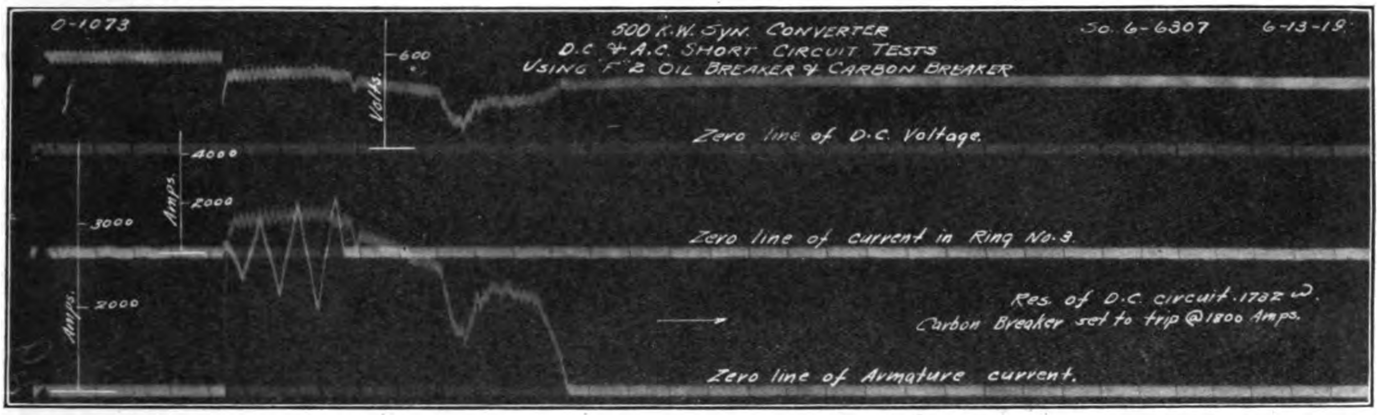


Fig. 12

compensated. In fact, with the relatively low a-c. armature reaction at the instant of short-circuit, the resultant armature ampere-turns may be even greater than the commutating-pole ampere-turns, which means that the commutating-pole flux is actually reversed. This of course depends upon the relative amount of the commutating-pole m. m. f. expended in bucking down the armature m. m. f. and in forcing the flux across the gap. The larger the proportion of the ampere-turns expended in the commutating-pole air gap, or its equivalent, the less will be the effect of the armature reaction upon the commutating-pole flux and hence upon the commutation and flashing of the machine. Furthermore, on extreme overload or short circuit the machine falls back in phase similar to a synchronous motor carrying load with the result that the a-c. armature m. m. f. lags (in space position) with respect to the d-c. armature m. m. f. which is fixed in position by the position of the d-c. brushes. Therefore, even after the first instant of short circuit and after the a-c. m. m. f. has established itself the resultant armature reaction is still proportionately higher than the increase in load due to the relative shift in the position of the a-c. and d-c. armature reaction. This produces a result similar to the conditions in the first instant of short circuit, *i. e.* an under-compensated machine. Trouble from this source can also be minimized by increasing the strength of the commutating-pole field relative to the armature.

Sudden changes in the applied frequency to the converter is equivalent to the machine being out of phase and produces similar results from the standpoint of flashing. In fact, our attention was first called to the importance of the relative strength of the armature and commutating-pole fields by a case of trouble from this source in connection with flashing on a 1000-kw. 600-volt 25-cycle converter at the plant of the Philips Sheet & Tin Plate Co. at Wierton, West Virginia in the early part of 1917. This converter is connected to the secondary of an induction motor which drives a rolling mill and which is subjected to very sudden changes in load. These sudden changes in load produce sudden changes in speed of the induction motor with a resulting sudden change in the frequency applied to the converter which causes flashing in a manner referred to above. A change was made in the commutating-pole circuit to strengthen the commutating-pole field in an effort to eliminate the flashing trouble. This change was to place, approximately, three-quarters of an inch of brass liners at the back of the commutating pole. New commutating-pole windings to supply the additional ampere-turns required as well as new commutating poles to allow space for the brass liners, were also required. These brass liners being of conducting material, also have a tendency to damp out the pulsations of the commutating-pole flux caused by the pulsating armature reaction. This change practically

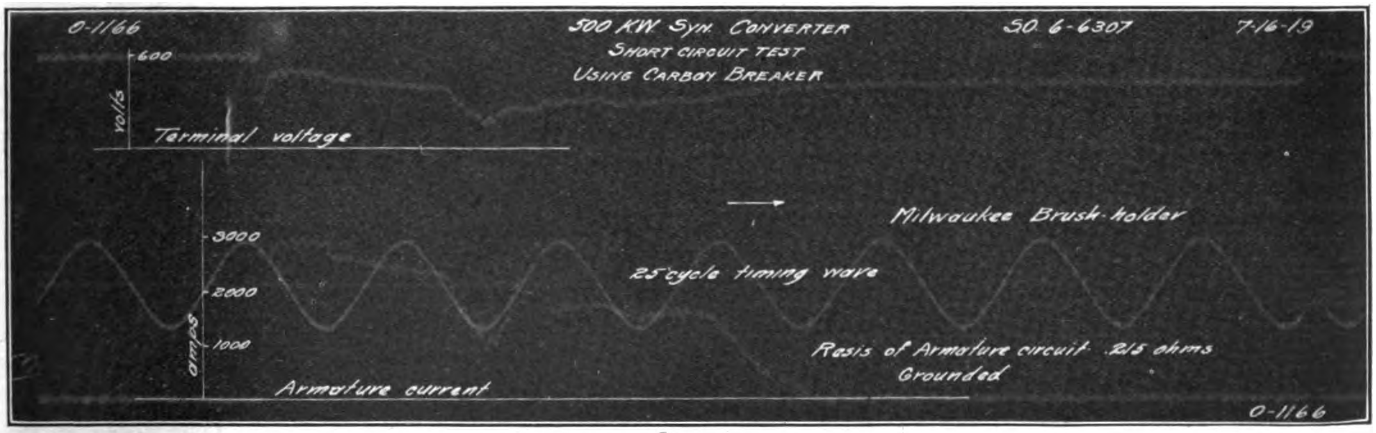


Fig. 13

eliminated the flashing trouble on this machine and showed a field for development along this line.

Quick-Acting Circuit Breaker

Tests made in connection with a modified high-speed railway-type breaker have been previously referred to

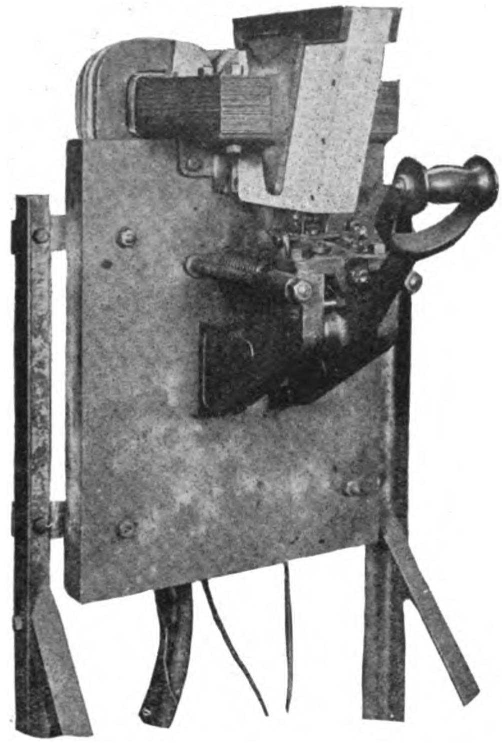


Fig. 14

see Figs. 2 and 3. This breaker has sufficient speed to protect the machine in most cases but is not suitable for this size machine on account of its limited continuous current carrying capacity. Its high speed is due to some extent to its over-rated application in this case.

A 2000-ampere high-speed breaker now being developed and which is still in the experimental stage was also tried out with some success. However, even with this breaker complete protection could not be obtained. Illustrations in Figs. 14 and 15 show front and rear views respectively of this breaker. On dead short circuit this breaker has a speed of, approximately, 0.014 second for complete opening. The arc tips begin to open in approximately 0.004 second. Dead short circuits on the machine when protected by this breaker are shown in Figs. 16 and 17. In these cases the rate of initial increase in current is limited to approximately 2,100,000 amperes per second, about 65 per cent of the normal rate of increase. This reduction in rate of current increase is such that the speed of the breaker is sufficient actually to limit the maximum value of the short-circuited current. This lower rate of increase in the direct current is due to a 0.15-millihenry reactor which was put in the circuit. The primary purpose of the reactor is to shunt the trip coil of the breaker so as to give a greater rush of current through the trip coil and thereby increase the speed of operation of the breaker. Although this reactor was effective in increasing the speed of the breaker as well as limiting the rate of increase in the direct current, a very undesirable and vicious voltage was induced in the coil upon the opening of the d-c. breaker, which in some cases appeared to re-establish the arc across the breaker.

This breaker was about as much underrated as the modified railway breaker was overrated on this application and it is believed that it would have a slightly higher speed on higher currents than dealt with in this case. A smaller breaker with lighter moving parts is now being considered on which it is expected to obtain higher operating speed.

Some very interesting high-speed photographs of the machine when flashing and when protected by this breaker are reproduced in Figs. 18 and 19. The camera used in taking these photographs has twenty-two stationary lenses with a rapidly revolving shutter in the rear which opens them in rapid succession. The time interval between each exposure is of course dependent upon the speed of this shutter which is variable. The progression of the phenomena is in the

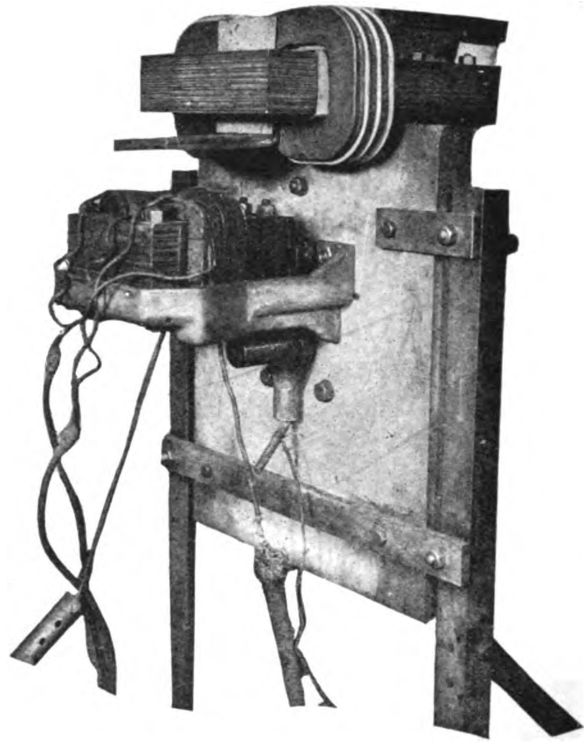


Fig. 15

order of the numerals on the plate. The pictures marked with the sub letter S were taken at the same instant (by two different lenses) as the picture marked with the corresponding number without the sub letter S. When properly mounted these pairs of pictures can be viewed to a great advantage through a steroscope which brings out the third dimension or depth of the picture.[1]

1. A detailed explanation of the construction and operation of this camera is given in an article by Mr. J. W. Legg in the December 1919 issue of the *Electric Journal.*

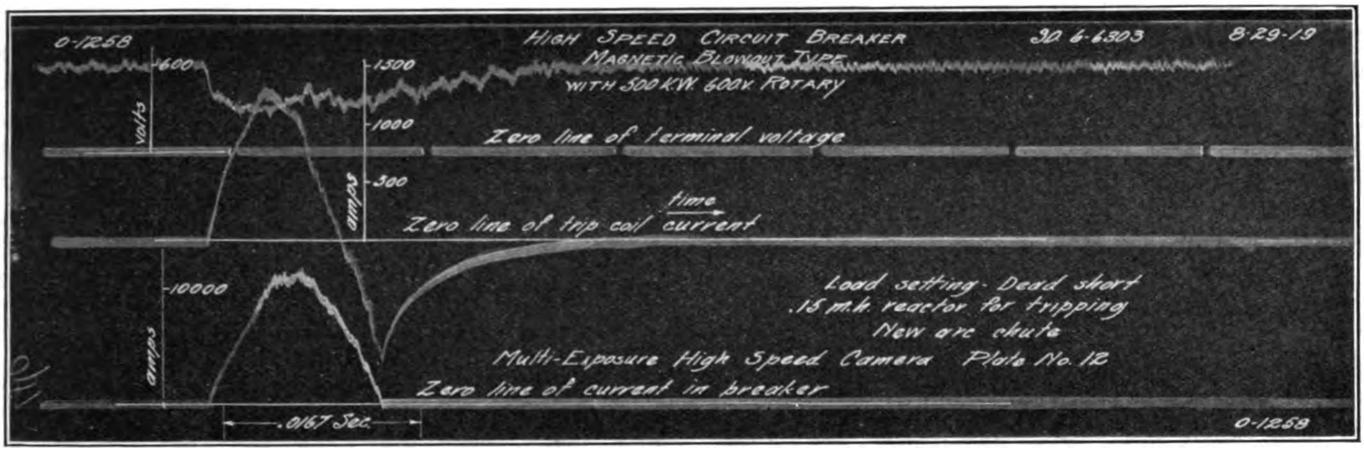


FIG. 16

Fig. 18 which corresponds to oscillogram in Fig. 16 shows a picture of both the machine and breaker when flashing. There is approximately 0.0018 second interval between each picture. Pictures 1 and 17 which show the beginning and the end of the phenomena shown on this plate overlap and are shown together. The small light spot in the lower left hand corner of picture 1 shows the beginning of the arcing. The breaker is not yet visible. In picture 2 the arcing on the machine is increasing the several spots of light representing sparking under the several brush arms, and the beginning of the breaker opening is shown in the upper right-hand side of the picture. In picture 3 the flashing is still progressing, and so on to picture 7 where the breaker has completely opened and the machine flashed over. The machine continues to flash throughout the length of this series of pictures. Fig. 19 which corresponds to oscillogram Fig. 17 shows a closer view of the flashing on the machine alone.

Flash Suppressor

The flash suppressor as applied to converters is simply a high-speed switch actuated by the short-circuit current, much in the same manner as a circuit breaker, which short-circuits either all or a part of the collector rings (usually three or six in the case of a six-phase machine.) This reduces or kills the voltage on the commutator to such an extent that it prevents the machine from flashing over. A detailed explanation of the flash suppressor is given in an article on this subject by Mr. F. T. Hague and Mr. N. W. Storer in the May 1918 issue of the *Electric Journal*; and its particular application to the generators of the Chicago, Milwaukee and St. Paul motor-generator sets is given in an article by Mr. Daivd Hall in the January 1920 issue of the *Electric Journal.*

The operation of the flash suppressor means practically a short circuit on the a-c. system through the converter transformers. The alternating current drawn on a dead d-c. short circuit where the high reactance transformers are used for compounding purposes, was only 15 to 20 per cent higher with the suppressor in operation than without. Thus on dead d-c. short circuit the suppressor did not add so much to the duty of the machine and a-c. system. However, each overload on the d-c. side above a predetermined value for the suppressor to operate meant a short circuit on the a-c. side. Another undesirable feature was the fact that the machine fell out of step and had to be synchronized again. In an effort to limit the heavy alternating current drawn by use of the flash suppressor and so eliminate this objection, tests were made with

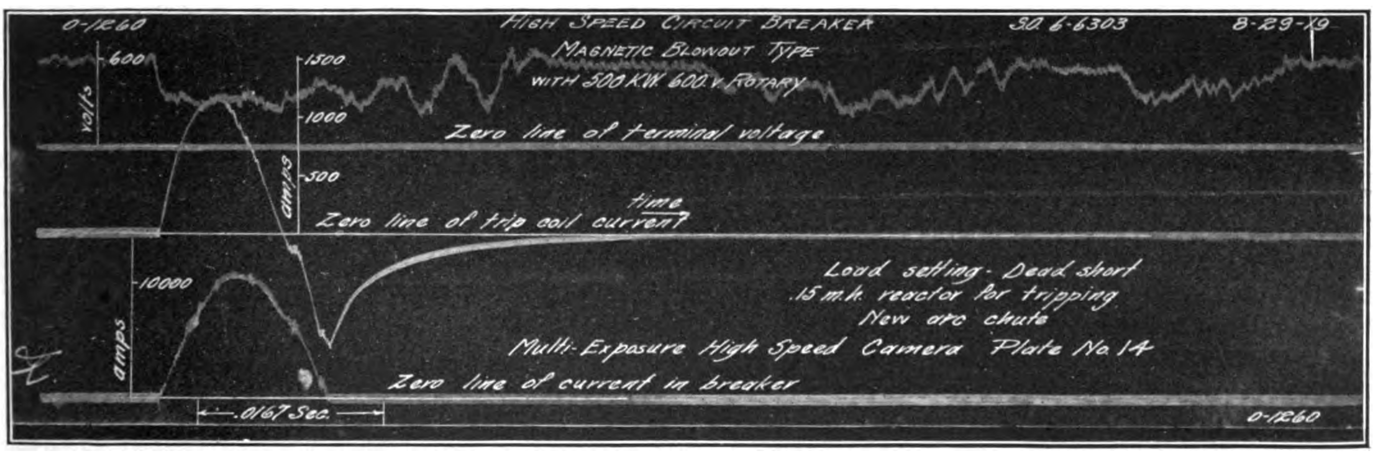


FIG. 17

inductance in the local suppressor circuit for the purpose of finding out the maximum value of inductance which could be used to limit the alternating current and still reduce the d-c. voltage sufficiently to give protection on the d-c. side. For each setting of inductance the d-c. short-circuit load was increased to the point of prohibitive flashing. It was found that in order to give protection the value of this inductance had to be such that upon the opening of the d-c. breaker the d-c. circuit breaker was put in the local leads of the suppressor circuit in connection with the above tests, so as to open the suppressor circuit and throw the machine back on the line. The trip circuit for the oil breaker was energized immediately after the opening of the d-c. breaker by means of an auxiliary contact on this breaker. Figs. 20 and 21 show tests in which the flash suppressor circuit was opened and the machine thrown back on the line. It was found that the sup-

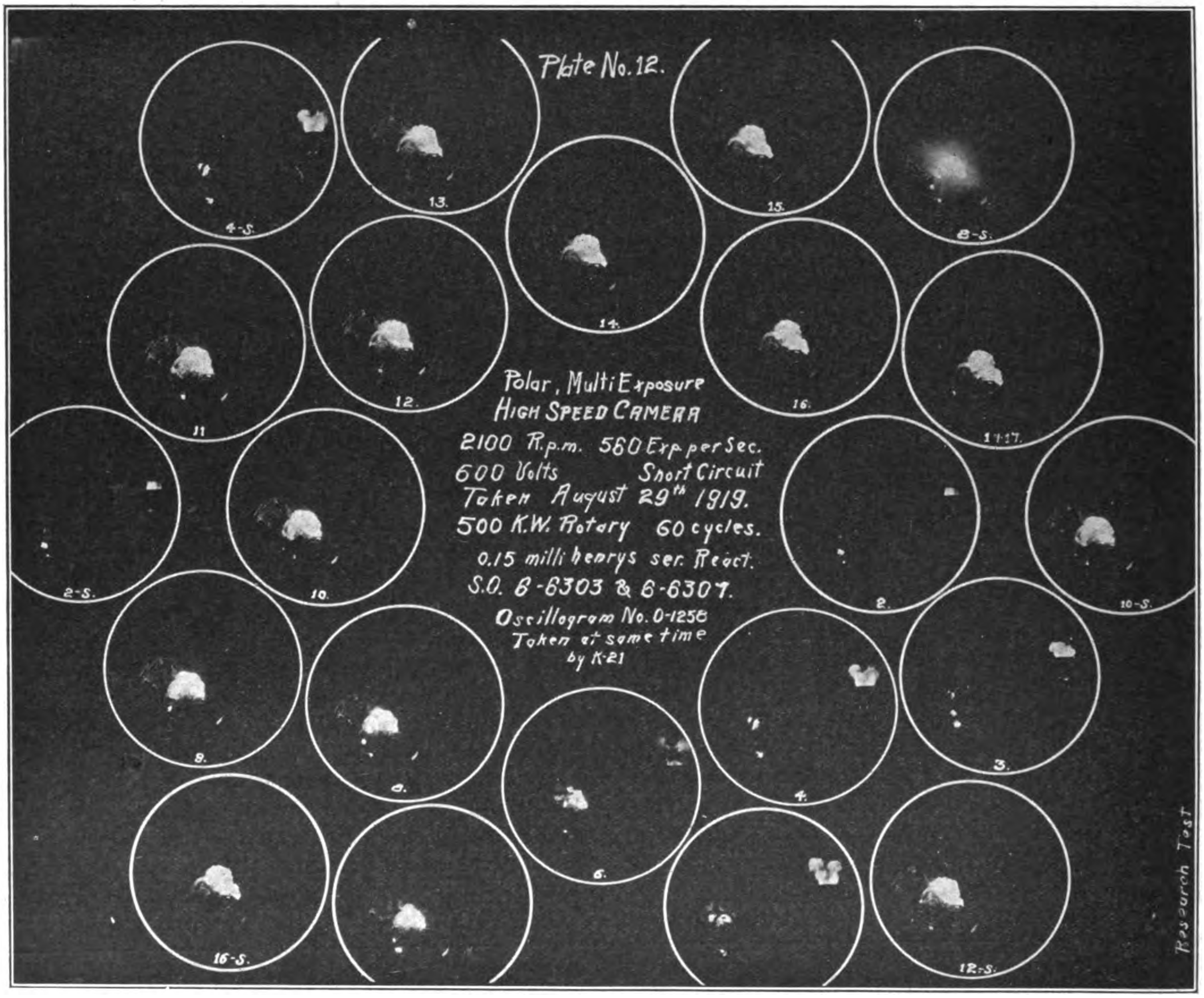


Fig. 18

voltage would not rise above the value it had dropped to due to the d-c. short circuit, *i. e.* there must be no appreciable rise in voltage when the d-c. breaker opens. Also the tests showed that reasonable protection could be had at about eight times full d-c. load without drawing over nine times full load alternating current, or at about 12 times full direct current without drawing over 10 to 12 times full load alternating current.

With the idea of eliminating the undesirable feature of having to re-synchronize the machine after the operation of the flash suppressor, a three-pole oil pressor circuit could be opened and the machine thrown back on the line in this manner without any particular disturbance up to the point where the induction in the suppressor circuit must be decreased (for protection to the d-c. side) sufficiently to cause the machine to fall out of step. This point is at approximately ten times full load. Some evidence of the tendency of the machine to fall out of step is shown by the slight oscillation in the d-c. voltage wave in Fig. 21. The oscillogram in Fig. 22 shows a short circuit of approximately 13 times load and the pulsations in the d-c. voltage wave show

clearly that this machine is out of step. The frequency of these pulsations corresponds to the slip frequency on the commutator and shows the extent to which the machine is out of step. When the suppressor circuit is opened and the machine thrown back on the line, when it is out of step, it flashes over due to phase displacement on the a-c. side regardless of the value of the d-c. load.

All of the above tests show clearly that the flash suppressor will give ample protection from flashing to the converter as far as the a-c. side is concerned. However, there are several problems connected with the application of the flash suppressor to synchronous converters, such as, the increased duty on the collector ring, disturbance to the a-c. supply systems and the machine's falling out of step, which have not yet been worked out.

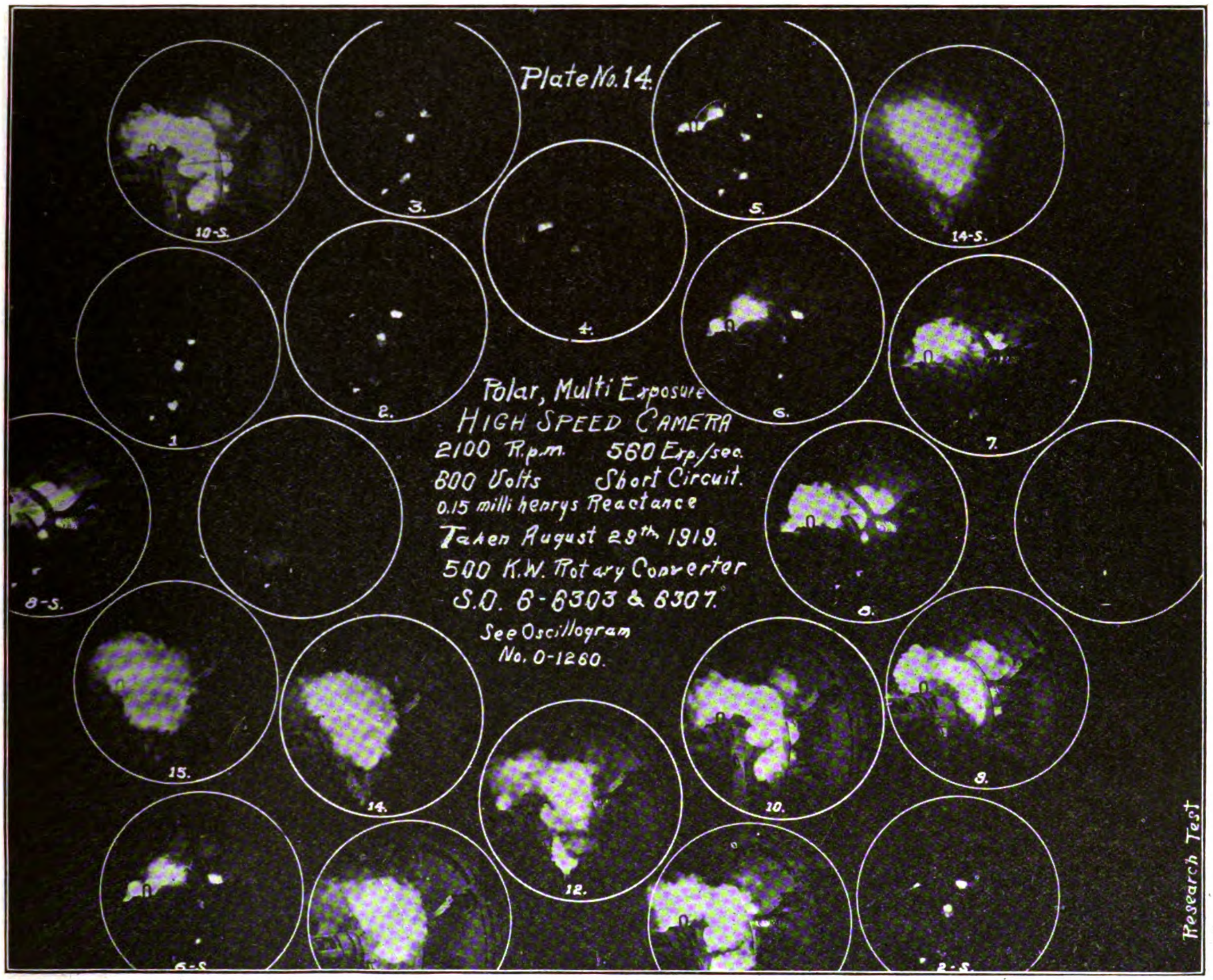


FIG. 19

Flash Guards or Barriers

Various forms of flash guards have so far proved to be unsuccessful. The general construction of these guards consisted of two continuous end rings, one at the back of commutator next to commutator necks and one at the front of commutator, with barriers between arms extending down to within approximately 1/32 in. of the commutator. These guards were made of asbestos lumber, a composition of asbestos and asphalt. Considerable trouble was experienced at first from the arc going under the front guard ring to the commutator *V* ring. This was remedied by making this front ring counterbored so that it extended over the face of the commutator a small distance as well as below the front end of the commutator. However, even this did not prevent the machine from flashing; with the arcing space confined by these guards the arc seems to become explosive and force itself to parts that it otherwise has no tendency to go. Furthermore, after several flashes the surfaces of these guards become so carbonized and covered with metal particles that they actually aggravate the flashing rather than prevent it. In fact, in several instances the guards were so carbonized and metal-smeared after the flash-over, that streamers would

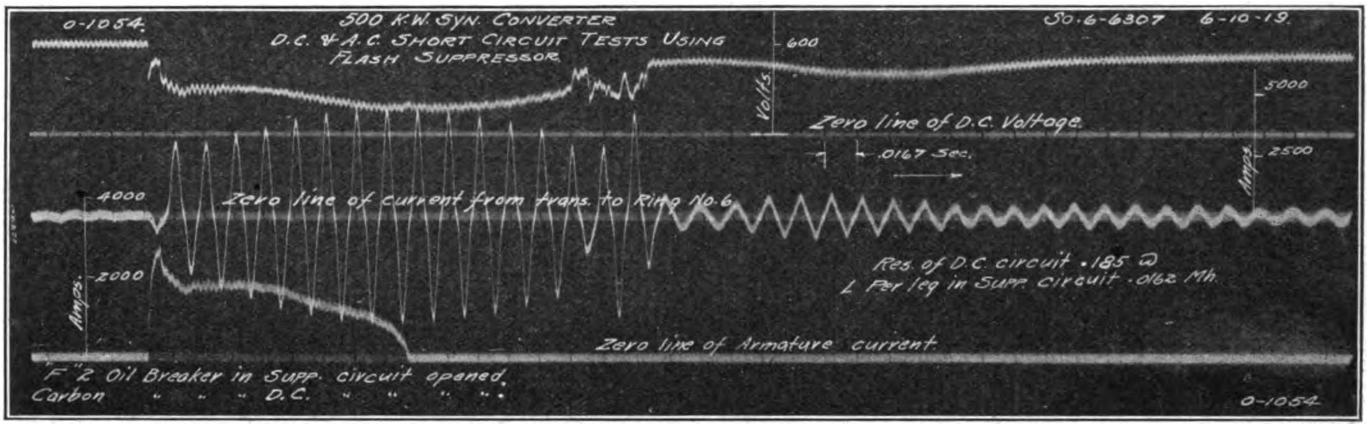


FIG. 20

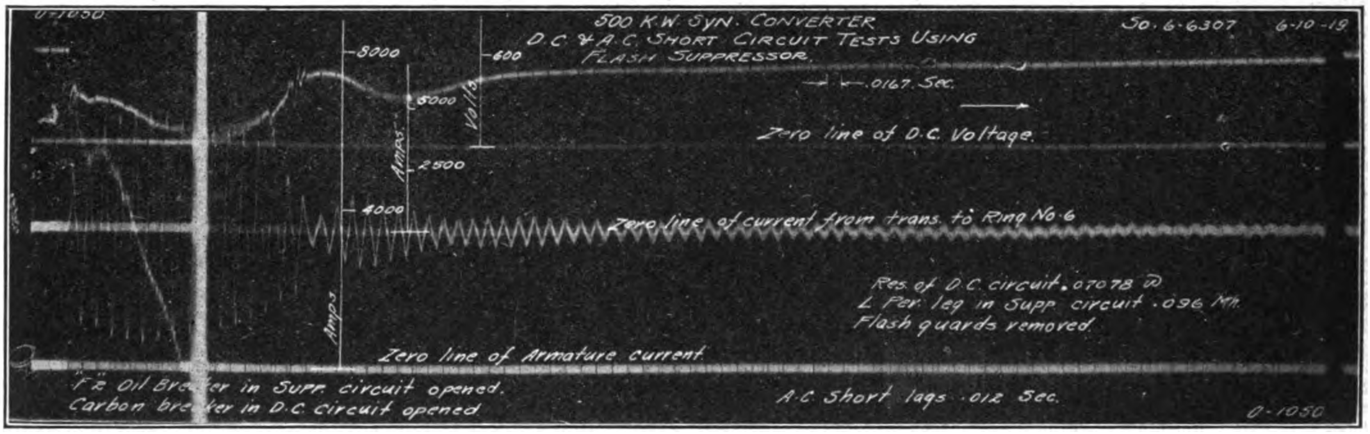


FIG. 21

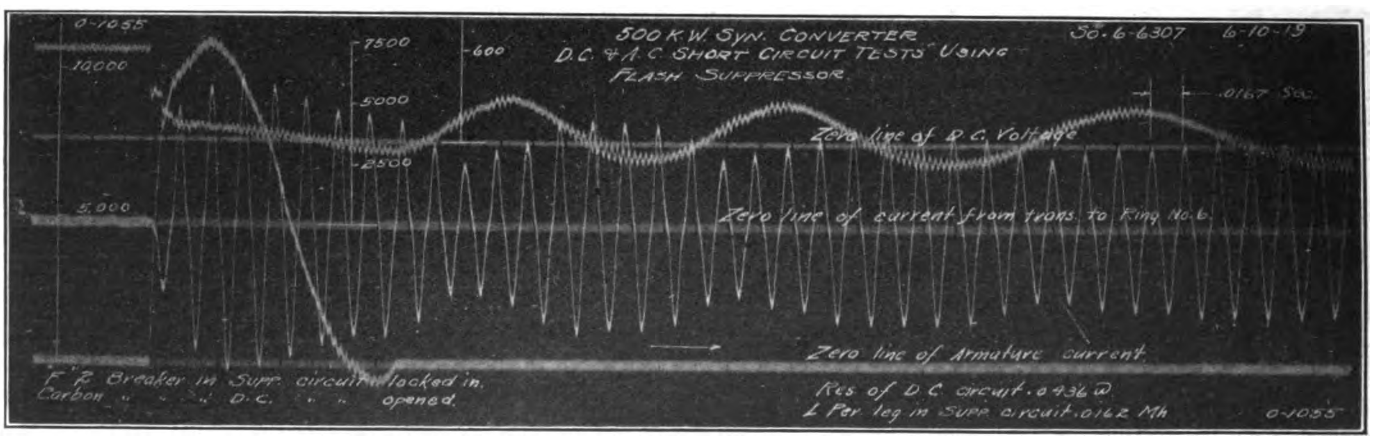


FIG. 22

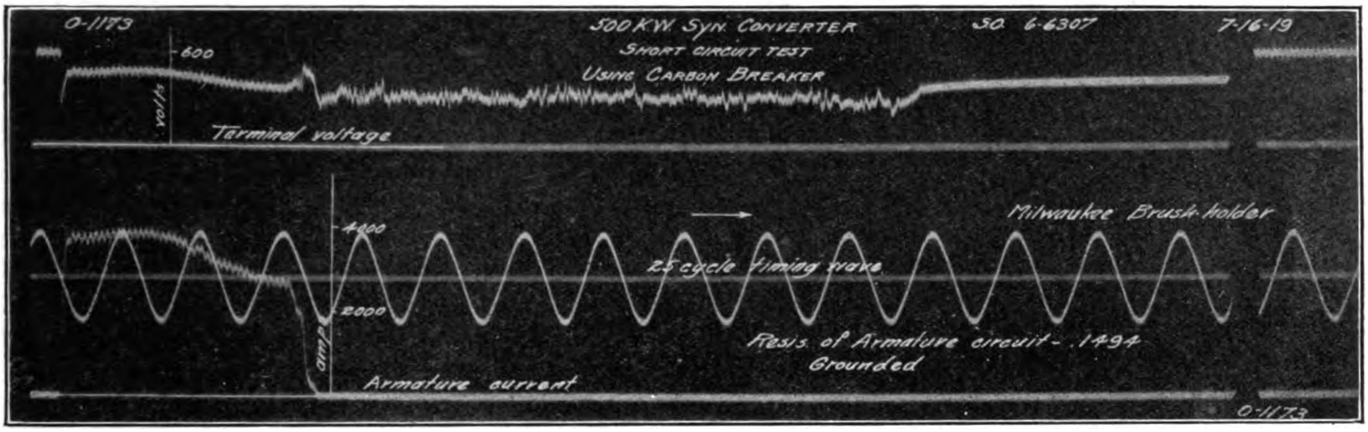


Fig. 23

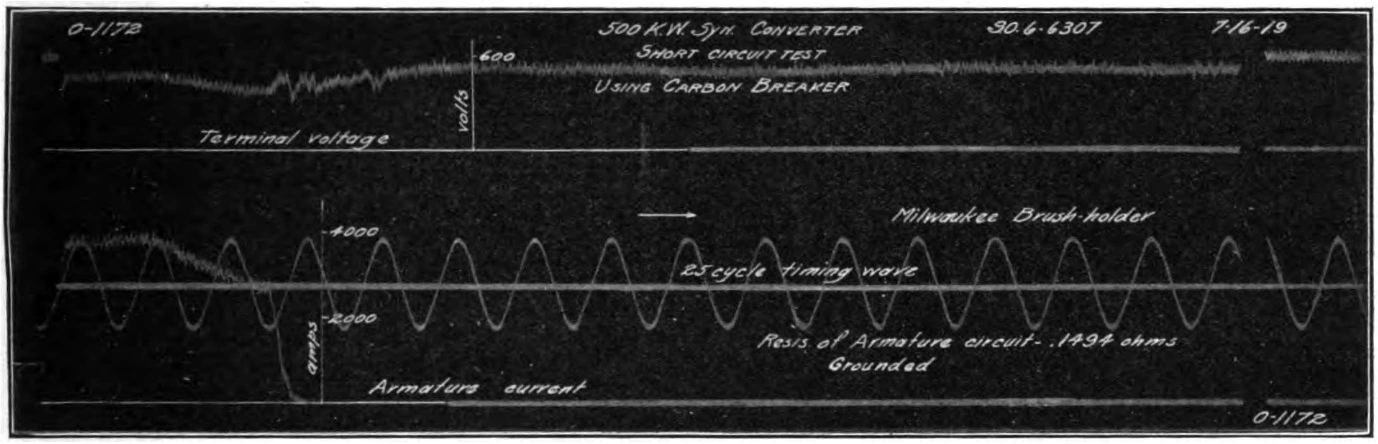


Fig. 24

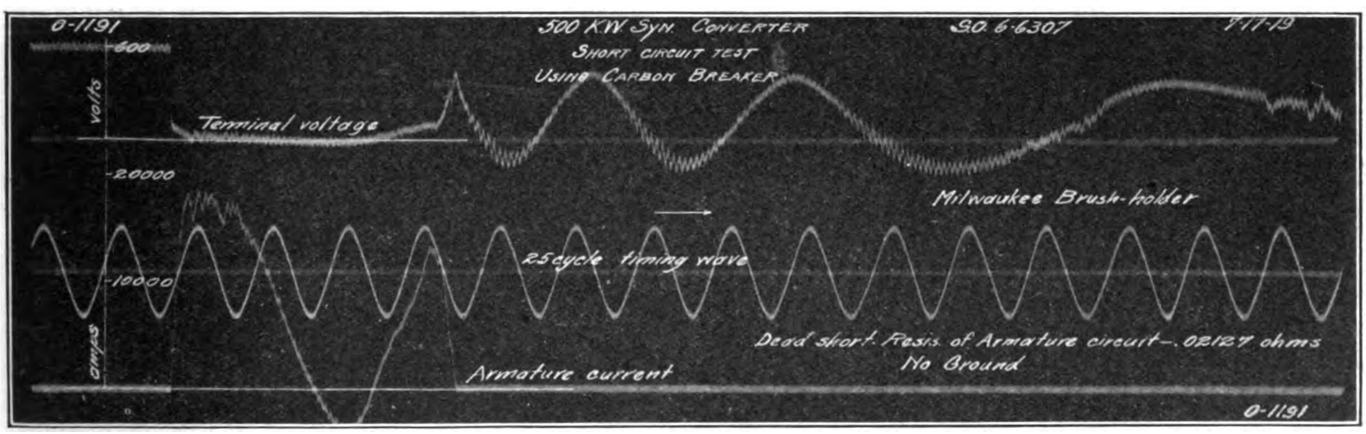
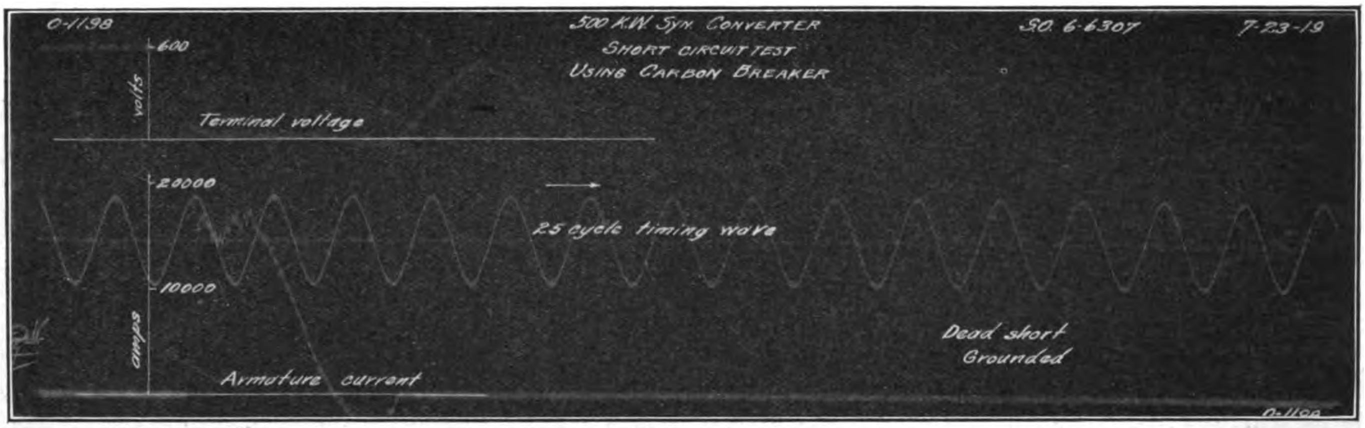


Fig. 25



- FIG. 26

run along the surface at no load and normal voltage. All tests indicated that these barriers should be of an open construction and as far away from the source of the arc as possible so as to give it sufficient room to expand and dissipate itself without becoming explosive. In other words the barriers should be next to the parts to be protected (as the pedestal and leading side of brush holders) and as far away from the arc as possible. This fact is borne out by oscillogram in Fig. 23. In oscillogram shown by Fig. 24 the machine flashed over to the front pedestal (no flash guards on machine). In an effort to keep the arc from jumping to the pedestal, the front ring, which had been slightly carbonized on a previous flash-over was then bolted back on front of the brush-holder brackets and the short circuit repeated as shown by Fig. 23. This time the arc jumped along the surface of the front ring between the two front brush holders on the two lower arms and practically demolished these two brush holders. Later this ring was fastened to the pedestal, away from the commutator and the source of the arc, and gave complete protection clear down to dead short circuit except for slight pitting of the brush holders.

This shows very clearly that the flash guards increase the tendency of the machine to flash over after they have become carbonized. No suitable material for this purpose which will not carbonize has been found so far. Best results have been obtained by protecting the pedestal with an arc shield and leaving as much space as possible on the commutator for the arc to expand. This also gives free access to the commutator, the back of which is one great disadvantage and objection to any form of flash guard. This same protection can be offered more readily and easily by insulating both pedestals much in the same manner as for the elimination of bearing currents. This, however, has the disadvantage that a dangerous voltage may exist between the pedestals and ground in case the armature becomes grounded. With the pedestals insulated this machine can be dead short-circuited with the ordinary carbon breaker with no particular damage to the machine except a slight pitting and marking of the brush holders. Figs. 25 and 26 show dead short circuits with the machine grounded and ungrounded under the above condition. Evidence is again shown of the machine falling out of step as discussed under the heading of flash suppressors. The fact that the d-c. voltage is pulsating undoubtedly prevents the arc from hanging on. It goes out when the d-c. wave passes through zero. For this reason a dead short circuit on a converter in connection with a slow-speed breaker does not appear to be as vicious or tenacious as a short circuit at a point just before the machine falls out of step and the d-c. voltage is maintained in one direction. This point is about 10 to 12 times load in the case of this machine. This is also about the point of maximum $E\,I$ output.

PRODUCTION OF ELECTRIC POWER AND CONSUMPTION OF FUEL

The Geological Survey has published a compilation of its data showing kilowatt-hours produced in each state by water-power as compared with the power produced by fuel. This report covers a four month period from February to July, inclusive, 1919. This table also shows totals of power so produced with the average daily output in kilowatt-hours and the percentage of waterpower output.

The figures showing the production of electric power by fuel in each state are divided so that they show the coal, oil and gas used in producing the power.

The report is based on the returns received from nearly 3000 electric power plants engaged in public service, including central stations, electric railways and other plants. Returns were received from plants whose aggregate capacity of generators is about 90% of the total installed capacity of generators of public utility plants. Estimates of the output of plants which did not submit returns were made from available information. The Geological Survey intends to issue supplements to this report as the data is secured.

Automatic Substations for Heavy City Service

BY R. J. WENSLEY

Westinghouse Electric & Manufacturing Co.

WHEN automatically controlled substation equipment was in the development stage, the general consensus of opinion was that its greatest field lay in relieving the smaller interurban systems of a greater portion of their substation operating labor. While many such systems have installed one or more automatic substations, they have not displayed the interest in the matter that was expected. In many cases the officials have professed their total inability to finance the new apparatus even though the investment would show a very attractive saving.

On the other hand, it is very gratifying to those directly interested in the subject, that the larger city street railway systems are eagerly taking up the question of rebuilding their distribution systems by taking full advantage of the decided savings made possible by automatic operation of the converting equipment. Orders received from this source have more than made up for the failure of the smaller roads to equal expectations.

The earlier street railway systems made little or no attempt to lay out a distribution system with economy or efficiency. Any location available was seized on as a power house site. Cables were run the shortest possible distance to the trolley and from that point the trolley was usually the only means of carrying the current. As service demands increased due to larger cars and closer schedules, the voltage drop became too great for satisfactory service even by the rather lax standards of those days. To remedy this the trolley voltage was gradually increased from the early standard of 500 volts to 550 and then to 600 volts and the feeders were run parallel to the trolley so as to help the voltage at the ends of the lines.

As the traffic demands increased another factor entered into the distribution problem, that of electrolytic destruction of underground metallic structures such as water pipes, gas mains and so forth. This necessitated heavy copper feeders in parallel with the rail to prevent the returning current from seeking to travel over the underground piping system. The negative booster was also freely used to compensate for the drop in these return feeders. This of course was practically pure waste so far as efficient utilization of the power was concerned since the entire output of the boosters was expended in heating the cables. It was however a good preventive of electrolytic troubles and therefore widely used in spite of its wastefulness.

All this time the source of power supply was almost invariably a slow-speed d-c. machine operating at 550 to 600 volts, and direct-connected to a reciprocating engine.

Presented at the Pittsburgh Meeting of the A. I. E. E., March 12, 1920.

These units grew to unwieldy size in the attempt to keep up with the ever increasing demands of the public for more transportation facilities. The engine driven alternator and then the turbo alternator came to the front as the most economical method of power generation and the railway substation followed soon after. There were of course, railway substations in operation long before the turbine became popular but these were exceptions to the rule.

Some of the larger cities soon installed a distribution system composed of one or more central steam plants with a number of large substations located in various parts of the city. Owing to the cost of operating labor these were kept down to the least possible number even at the expense of considerable investment in feeder copper. There are many of the old systems still in operation with an unwieldy amount of feeder copper in the air and with I^2R losses amounting into the millions of kilowatt hours per year. Poor trolley voltage with consequent slowness of schedule speeds is a natural result of this. The possible savings to be had from reduced copper losses, reduction in running time and decreased amount of motor repairs by rebuilding the distribution system would in many cases enable a property to make a better showing of earnings than it is making at the present time.

The development of automatically controlled substation equipment has now placed in the hands of the distribution engineer a possible method of reconstruction that is little short of ideal. Substations can now be scattered about without the specter of heavy and ever rising operating labor expense to be watched. The increase in the number of substations enables the holding of good trolley voltage without the heavy expense in large feeder capacity as has previously been the case. Trouble due to electrolysis is greatly minimized and in many cases entirely eliminated by the increase in number of substations.

These substations are of course not one hundred per cent efficient so care must be used in applying this remedy that it not be overdone. Sizes of machines and stations must be carefully calculated so that the load factor will be as high as possible. In deciding on the best sizes of equipment to install, several factors must be considered. Interchangeability is always desirable and therefore there should be as few different sizes of machines as consistent with economical operation. Wherever possible the machines in any one station should be of the same size so that their places in the operating schedules may be interchanged. In most city applications two machines will prove to be the most desirable number for an automatic station with space provided for a third machine to take care

of future growth. In most cases this problem of added capacity can be better solved by the installation of additional substations when the load grows too great for the original installation of converting equipment. This latter method keeps down the feeder copper requirements.

Where two machines are selected for a given location each one must be capable of carrying the normal off peak load without assistance. The combined capacity must be sufficient to take care of the peak load. In some cases this will result in more capacity than necessary during the off peak period, and in other cases just the reverse, depending on the off peak load being less or greater than half the peak.

By selecting machines of combined continuous capacity equal to the r. m. s. value of the peak load, a reasonable reserve capacity is allowed since the two-hour rating will probably allow one machine to pull over the peak if the other is out of service. To help in such cases, a limited number of feeders should be run through from one station to another so that the feeder may be opened in the station in trouble thus transferring a portion of its load to an adjacent station. The automatic load limiting resistances supplied as part of a railway automatic substation will also help out in such cases at the expense of the trolley voltage.

To illustrate the way in which the problem of applying automatic substations to city service should be approached, a city of about 300,000 population has been selected to serve as an example. This city is now served by an excellent example of the old method of centralized distribution. Fig. 1 shows in a general way the stupendous amount of feeder copper that has been installed in the attempt to give good service. The two plants are about three-quarters of a mile apart on the same side of the city and about one mile from the loop district where lies the greatest load concentration.

The heaviest loaded lines are on the opposite side of the city from the power plants. The lower plant is the oldest one and is mainly equipped with reciprocating units. The total d-c. capacity of this plant is about 8000 kw. The upper plant is a modern turbine station which supplies power for several interurban systems. In this plant are located three 2000 kw. of synchronous converters. This gives a total d-c. capacity of about 14,000 kw.

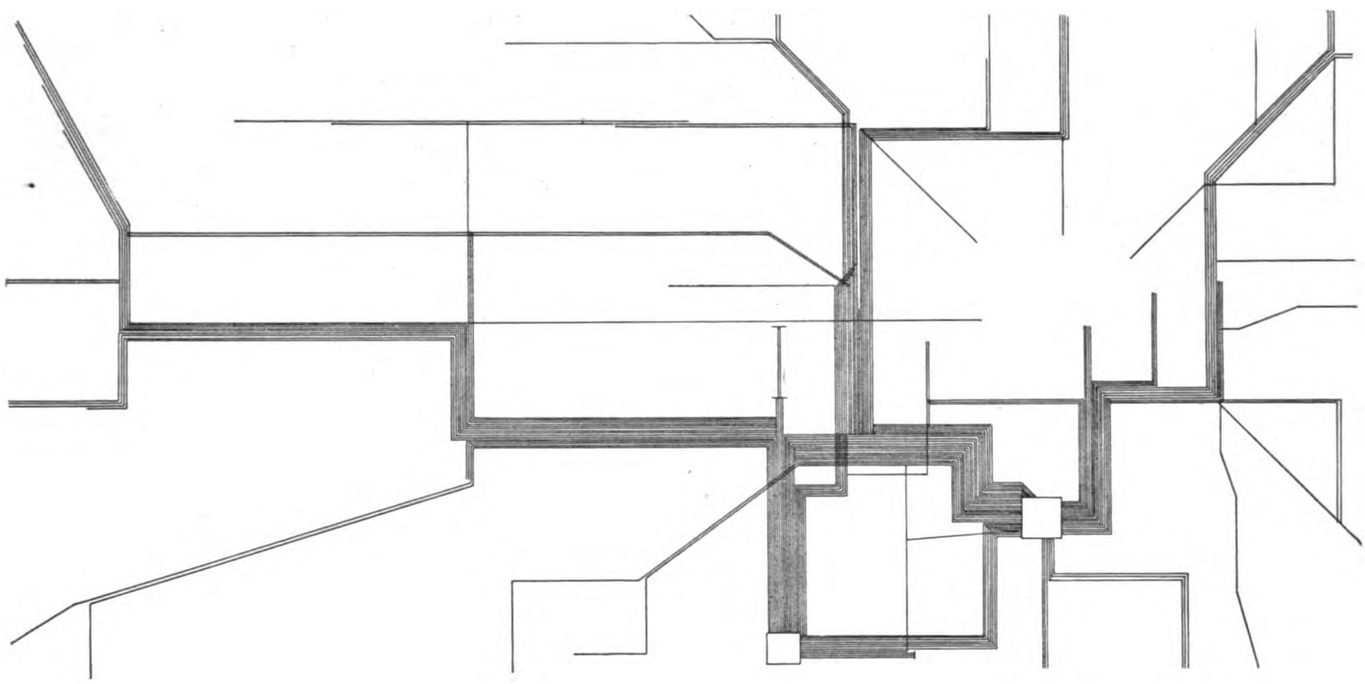


Fig. 1

Most of the feeders shown in the cut are 1,000,000 cir. mils. There is a total of 25,800,000 cir. mils in feeders both positive and negative leaving the old plant, 23,000,000 cir. mils leaving the new plant and 8,000,000 cir. mils in tie lines between the plants. One of the heaviest loaded lines runs from the loop directly away from the plants with the end of the line about seven miles distant measured along the feeder run.

Of this total feeder capacity about 40,000,000 cir. mils are in the positive feeders, the remaining being in the return feeders. The average length of feeder to the center of its load is about two miles. The peak load on the two plants is about 22,000 amperes. Assuming for estimating purposes that the rail and return feeder drop will be somewhere near equal, we find that at peak load the average voltage at the load centers will be 475 volts with 600 volts on the station

bus bars. The I^2R losses reach the enormous value of 2750 kw. or 20 per cent of the total d-c. input, over the peak period. The average trolley voltage at the car will be somewhat less than that given for the load centers. In many cases the voltage on the car is so low that it is almost impossible to read news print during the evening rush hour.

This city operates about 300 cars during the periods of heavy traffic most of which are double truck, 20 tons in weight with two 60-h.p. motors geared for 27 miles per hour. The schedule speed is about six miles per hour during the evening rush hour and even this can hardly be held. Due to the low average voltage the cars cannot accelerate rapidly as they should and bunching soon occurs which only aggravates the trouble.

The problem is to lay out a new distribution system which will reduce the transmission losses to a minimum, raise the average trolley voltage to a reasonable value, keep the stray earth currents to a minimum, and at the same time avoid raising the expense for operating labor to an undue amount. All this must be accomplished at the lowest possible net cost.

As a preliminary to deciding on the size and location of substation equipments a spot map of the system should be prepared based on the rush hour schedules. A sample of this is shown in Fig. 2. A factor which upsets the spot map as shown is the fact that there are fourteen interurban lines entering this city all of which operate fairly heavy cars; 45 tons weight with four 90-h.p. motors geared for sixty miles per hour would represent the average. In laying out the power supply it has been asseumd that two of these cars are at the center of each line which they use for entering the city.

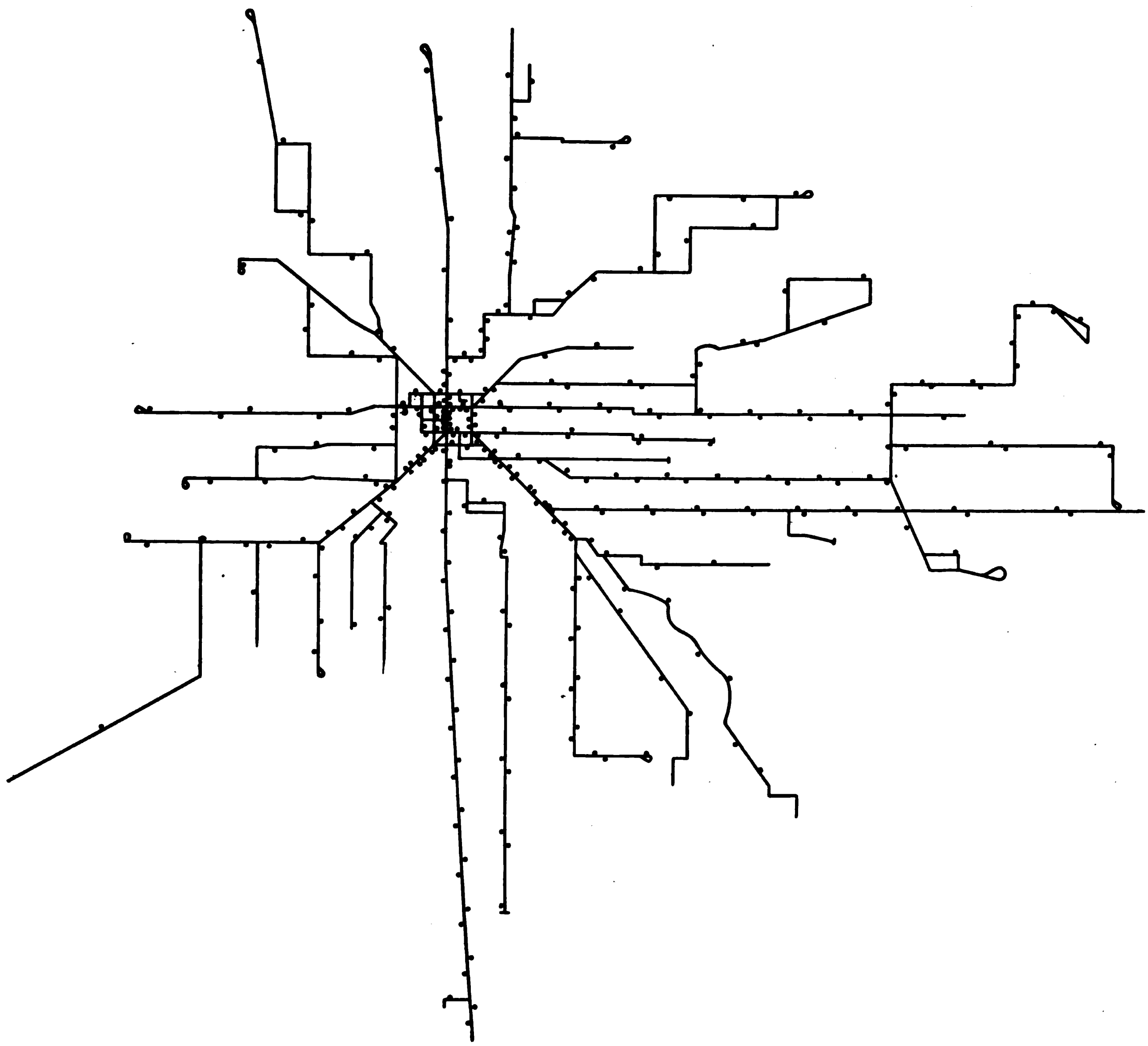


Fig. 2—Spot Map—Automatic Substations

Certain other conditions such as heavy seasonal loads must be considered. There are in this city three parks that are heavily patronized and a fair ground that is a very heavy peak for one week in the year. Such considerations as these have been used

to modify the strictly mathematical method of locating the new substations. This method is the one described in Richey's handbook as having been used to lay out the feeder system in Chicago, and consists of assuming that the distributed load on each line is concentrated at the center, then, treating the loads as actual weights, find the center of gravity. This locates the substation in the ideal position to feed its section. This ideal location is of course seldom practical and due consideration must be had for local conditions.

In figuring the spot map shown in Fig. 2 the average current per car has been taken as 53 amperes. The interurban cars have been figured as equal to two city cars. The city has been arbitrarily divided into nine districts for the purpose of apportioning the substation capacity. Care was taken in making this division to keep each section down to less than 2000 kw. in possible load as this seemed to be the largest size station that would be advisable on this size of system, having due regard for investment in feeder copper. The center of gravity was then found for each section and the substation located as near this point as a study of local conditions would warrant.

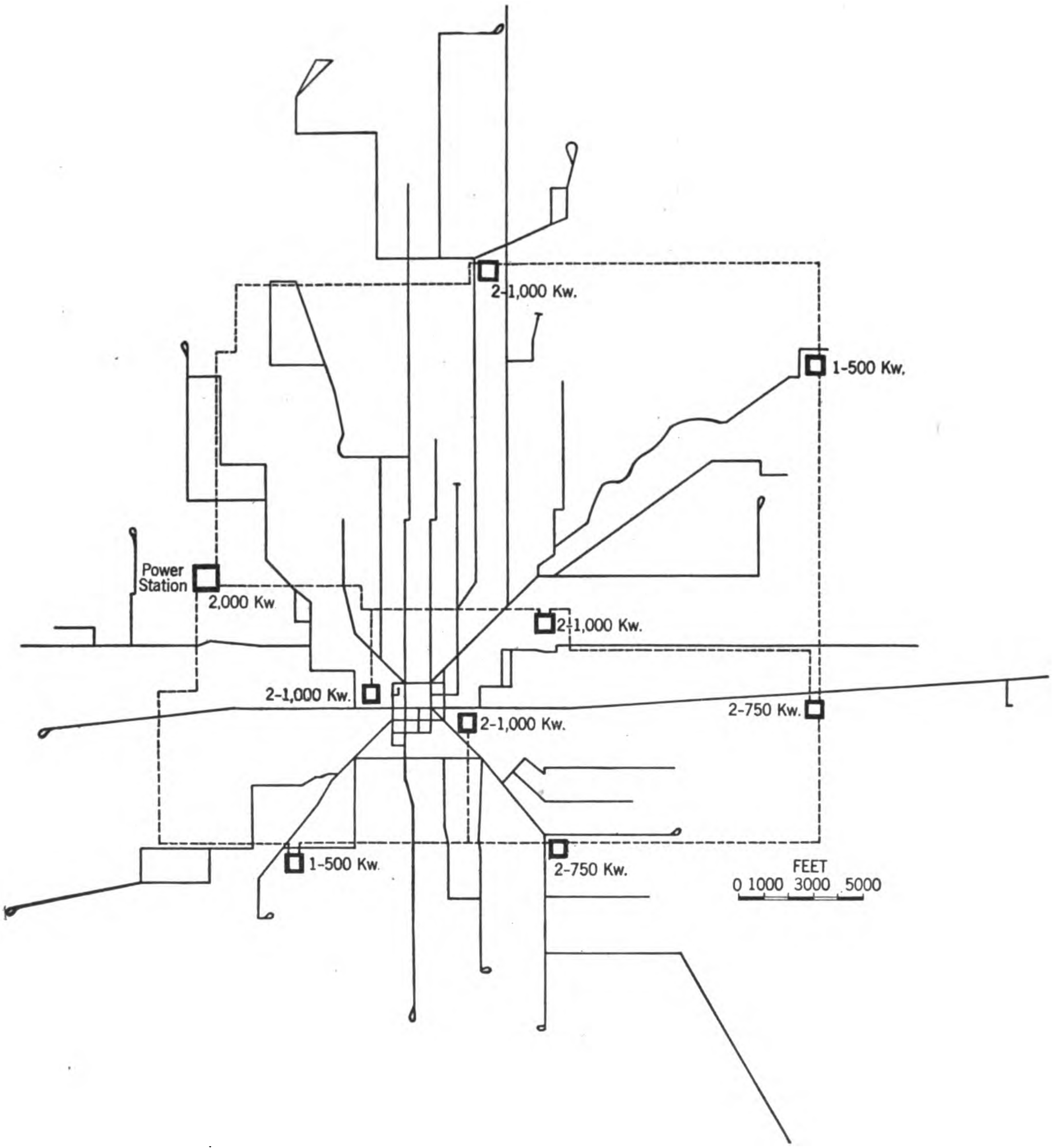


Fig. 3—Proposed Substation Layout—Automatic Substations

The two substations feeding the congested portion of the city were located on each side of the loop district just far enough away to be on the edge of the underground district. This is desirable from the standpoint of economy in installation, although the most desirable location from a standpoint of copper loss and feeder

copper would be right in the center of the loop. This would however result in excessive investment charges for real estate and underground construction. Locations east and west of the center were chosen rather than north and south because of real estate values.

The final location decided for these substations is shown in Fig. 3. The high-tension line locations were picked out by the superintendent of distribution of the street railway company with a view to using as much of the present pole line as possible and of selecting streets for the necessary new lines where there would be the least opposition from the residents and the city authorities. The feeders form a ring bus around the city with a tie line across the center.

The intention is to sectionalize the feeder in each substation and equip the section breakers with reverse-power relays so that any section will be cut out in case of trouble, thus leaving the entire system in operation with the exception of the damaged portion of the line. Owing to the local situation with regard to the telephone companies and the city authorities the maximum voltage which it would be advisable to use above ground is 6600. While this is not the most economical voltage for the amount of power and the distance, it has been adopted because of the great expense of underground high tension feeders at 11,000 or 13,200 volts.

At this voltage the feeder belt may be of 4/0 wire, and the cross tie line of 350,000-cir. mil cable which will give approximately 5 per cent power loss in the a-c. system at full load.

The substations as laid out have the following capacity machines installed: Three with two 1000-kw. converters each; Three with two 750-kw. converters each; Two with one 500-kw. converter each; One of the existing 2000-kw. machines to be retained at one of the steam plants. Total converting capacity installed 13,500 kw. Total peak load at present time 13,200 kw.

While this is apparently only sufficient nominal continuous capacity for the peak, it must be remembered that 20 per cent of this peak is lost with the present feeder arrangement so that if the feeder losses can be reduced to 5 per cent this will leave an actual surplus capacity of 15 per cent. This taken with the two-hour overload rating of the converters will give ample margin of reserve capacity.

The feeder calculations are based on maintaining an average voltage of 550 at the car during the evening rush hours. This property now has the equivalent of approximately 110 miles of 1,000,000-cir. mil copper in the distribution system. With the new substation locations we find that the rail resistance is within allowable limits in nearly all parts of the system. In only a few places will negative feeders be required and these will be quite short. With the widely distributed sources of d-c. energy, the carrying capacity of the trolley wires themselves become an important factor, in the distribution of the 600-volt current.

Of the present feeder system it will be possible to remove approximately seventy miles of 1,000,000-cir. mil cable or its equivalent. At 18 cents per pound this will amount to $205,380 which is the first important item of credit for the new installation.

The old d-c. plant should be scrapped entirely and the proceeds applied on the new equipment. It is estimated that the second hand and scrap value of this plant will be at least $100,000.

The I^2R losses on this system were calculated last year and the value of the current lost in the feeder system only, not including local track and trolley losses, was figured as being $100,000. These figures are not vouched for by the writer but as can be readily imagined from the description of the feeder system, this amount does not seem unreasonable. Since approximately one third of the feeder copper is to be left in service we will assume that the copper losses in the remaining feeders will be in proportion to the amount now in service. This will give us a saving in copper losses amounting to $66,000 annually.

If the rush hour schedules of each car are so speeded up as to save five minutes on the rush hour trip morning and evening, with 300 cars and with platform labor at 40 cents the annual possible saving will be $14,600.

The automatic substation buildings should be of the most simple type of construction possible with no heating apparatus and with no accommodations for operators. If extensive repair work becomes necessary in the winter time a portable electric heater can be installed. By constructing this type of building absolutely without ornamentation, the cost should not exceed $40 per kw. complete. Twenty-five miles of a-c. line will be required which can be partly installed on existing poles. The cost of this should not exceed $5000 per mile.

Gross cost of the new system;

11,500 kw. of substations at $40	$460,000
25 miles of line at $5,000	125,000
Reconstruction of feeder system	25,000
Power house equipment, transformers, etc	100,000
Total cost of automatic substations	$710,000
Credit power plant scrap	100,000
Credit copper removed	205,380
Net cost of automatic substations	$404,620
Fixed charges at 15 per cent	$75,693
Annual operating labor	7,000
Gross annual charges against automatics	$82,693

Savings due to the new equipment;

Annual saving in copper loss	$ 66,000
Annual saving in platform labor	14,600
Annual saving in labor due to shutting down of old power plant	50,000
	$130,600
Annual cost of substations	$ 82,693
Net operating credit annually	$ 47,970

In addition to the credit shown above, the system would have an increased capacity of 15 per cent or 20 per cent over the present one and would be attracting more patronage by better schedule speeds and better lit cars. It would also be in ideal position to take care of expansion in its business which is almost certain to come as the city in question is growing rapidly and is attracting many new and large manufacturing establishments all of which are locating well toward the outskirts of the city thus requiring increased transportation facilities.

If manually operated substations were to be installed it would not be possible to show an operating credit since only three or four stations at the most would be installed on account of the cost of operating labor. More of the old feeder copper would be required and the saving in copper loss would not be as large. More negative copper would be required to keep the return drop within allowable limits.

The entire equipment should be automatic in operation except the one converter retained in the power plant. One of the converters in one of the loop stations would be set for continuous operation so that night operation would be taken care of. With the heavy amount of feeder copper still remaining, it is doubtful if the voltage drop caused by the night cars would start the outlying substations.

If in practise this assumption should prove not warranted, then it would be necessary to install time switches or pilot wires to prevent these outlying stations from operating at greatly reduced load with consequently poor efficiency during the night.

Many modifications of this layout are possible without materially altering the saving shown. The writer feels that many such interesting problems in automatic control will be met with in the next few years and that its use will spread even faster than the expectations of those who have been following its development. Automatically controlled substations have at this date been applied to railway work, both city and interurban, to Edison three-wire systems, to large industrial plants, to synchronous condenser equipments, and to coal mines.

Heavy steam railroad electrifications have not as yet been tackled although several such jobs have been estimated and it will only be a relatively short time until such an equipment will be installed on one or another of the heavy electrifications.

From an engineering standpoint there seems to be great possibilities in this field.

NEW INSTRUMENT FOR DETERMINING CO-EFFICIENTS OF REFLECTION

In the design of lighting installations and in the case of many other applications of illuminating devices, a knowledge of the value of the coefficients of reflection of walls, ceilings, or other objects may be of material assistance. The illuminating engineer, with the aid of tables and instructions issued by one of the lamp manufacturers in this country, can predict with a fair degree of certainty the illumination which will be produced by any given type of lighting installation if he knows the shape of the room and the light reflecting characteristics of the walls and ceilings.

At the present time, there is no instrument available outside the laboratory which will enable the engineer to measure the coefficient of reflection of surfaces. Even when the measurements are made in the laboratory, the process is very difficult and tedious, and subject to rather large uncertainties. Several methods have been used, but most of them have given incorrect results because of an error in the value assigned to the standard surface used.

In order to remove the uncertainty in the value assigned to the standard s rface, and to develop an instrument which could be applied to the measurement of surfaces in place, a new instrument has been developed after extensive experiments, and a much better standardization of a reproducible surface has been made. This instrument is light and portable, and can be used with any one of a number of types of portable photometers, giving results which are reliable.

The instrument which has been developed is called a reflectometer. Aside from the photometer, which measures the light intensities, it consists of a small metal sphere from which a segment has been removed, leaving about nine-tenths of its original surface. It is painted inside with a diffusing white paint, and a beam of light is projected through a small hole in the wall onto the surface which is to be tested. The test surfaces may be compared with a standard surface or with a flat surface painted with the same paint as the sphere. It is believed that this reflectometer will fill a very real need. *Tech. News Bul., Bureau of Stds.*

An International Institute of Refrigeration for reference and research was established last December at an International Conference on Refrigeration held at the Ministry of Commerce in Paris. Eighty-nine delegates representing forty different Governments attended the conference, and they elected a provisory committee to control the new Institute. A monthly report on refrigeration, containing a classification of all technical, scientific, and economic documents collected from all parts of the world, is published by the Institute in English and French. The Institute is located at 9, Avenue Carnot, Paris.

The Audion Oscillator

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The article covers the theory and operation of Audion oscillator circuits. It embraces phase relations in various circuits, frequency of operation, simplification of complex circuits, and the behavior of oscillators as a function of its many variables. Vector diagrams are given of the phase relations in several simple circuits. The similarity of more complicated circuits to the simple ones is illustrated and the manner of determining the mode of operation of them by resolving into simple ones is given. A series of curves showing the behavior of an oscillator as the six independent variables in the circuit are varied, is illustrated by a series of curves and a method of quickly and easily adjusting a circuit to its proper working condition is pointed out from them. The problem of securing high efficiency is also discussed and requirements toward that end are pointed out.

1. Introduction

AMONG the great inventions, developed in peace times but made use of in the late war are the radio telegraph and telephone. They are recognized as most useful instruments of commerce, especially as instruments for safe sea travel. The wide use possible of radio apparatus necessarily makes for wide use of its most important apparatus element—the audion or vacuum tube,—and causes anything said or written about the latter to take on more than usual significance. The audion is also extensively used in telephone work. These varied uses together with the great potential possibilities in other engineering fields make it necessary for the present day electrical engineer to know something of its construction and operation.

The audion itself has been described in many articles up to the present, De Forest (Patent No. 879.532), Armstrong (*Electrical World*, Dec. 1914) (*Proc.* I. R. E., Mar. 1915), Van der Bijl (*Phy. Rev.*, Sept. 1918), Vallauri (*L'Elettrotecnica*, Jan. 1917), Langmuir (*Proc.* I. R. E. 1915), and no attempt will be made to describe it here.

The audion, which is essentially an amplifier, is used for many other purposes. It is used to generate oscillations, detect oscillations, and modulate oscillations. The particular phase of its use to be discussed in this paper is that of generating oscillations. Audion oscillator circuits have to a certain extent been discussed by Armstrong, Hazeltine (I. R. E. April 1918) Vallauri, and in Bureau of Standard's Circular No. 74. Analytic studies of audion oscillator circuits were made by Hazeltine, Vallauri, the writer[1] and others. In this article duplication of existing published work will be avoided where possible.

2. Scope

An analytic solution for an oscillator circuit, although giving much useful information regarding an oscillator's behavior, does not give the information necessary for the design of such circuits for power. It neglects many of the important factors which must be considered in securing best power conditions. The principal factors so neglected are: (1) the actual characteristic curve, (2) filament emission other than that of temperature saturation, and (3) the power absorbed by the grid input circuit. Such solutions give transient conditions, or requirements for oscillation. The neglected factors, though affecting these somewhat, produce their greatest effect after oscillations have begun by limiting the expanding current in the transient state and bringing about the condition of stable, sustained, free oscillations. In conditions under which power is secured from an oscillator, all of these factors enter into the behavior of the oscillator and cannot be neglected. To treat analytically a circuit containing them leads to such complicated expressions that an experimental determination of the oscillator's behavior is much easier. The latter was therefore done and the principal results and deductions therefrom are given in the following pages.

In the study of oscillators, by experimental methods, the large number of variables entering into its behavior necessitates an extremely large number of experiments. It would be desirable, if space permitted, to give complete information regarding all these experiments. However most of them were of comparative unimportance or gave negative results and their discussion would be a waste of time. This paper will be confined to the more important matters, theory as well as practise, and where thought necessary experimental evidence will be given to support the statements made.

3. General Oscillator Circuits

An important trait, peculiar to all types of amplifiers, is that under proper conditions they may be made to produce free or sustained oscillations. Common examples are the electric bell, and the ordinary telephone set which can be made to "howl" by placing the receiver up to the transmitter. In both cases, variable current power is generated by a variable resistance, part or all is fed into an input operating device, phase relations in the input power are definitely set (this is especially observable in the bell), and a separate source of power (a battery) is used. The frequency is determined by the mechanical free periods,—the clapper and spring of the bell, and the diaphragms of the transmitter and receiver. A large number of purely mechanical oscillators might be named besides these two which are partly mechanical and partly electrical, but they all exhibit the same characteristics.

The audion, being essentially an amplifier, can also

1. In the course of publication.

be made to generate oscillations. The same circuit conditions are necessary as for the example given. They are,

1. A circuit to fix the frequency,
2. A feed-back arrangement to impress some of the power from the output back into the input,
3. The proper phase relations for the impressed input,
4. A separate source of power.

The frequency is usually fixed by one or more tuned circuits. Oscillators can be made in which the frequency is determined by a condenser and a resistance, or an inductance and a resistance, but they are unsatisfactory for many kinds of work and are seldom used.

The feed-back arrangements for transferring power from the output circuit to the input circuit are innumerable. Fundamentally they all come under the heads of inductive, capacitive, or resistive coupling, but there is no particular manner in which the coupling must be accomplished.

The proper phase relation in the input power is of vital importance as regards the oscillator's operation. It is as important as the setting of the eccentric on a steam engine. The exact relations required are pointed out later.

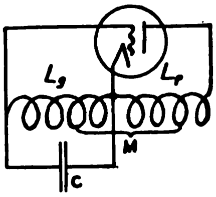


FIG. 1—FEED-BACK CIRCUIT

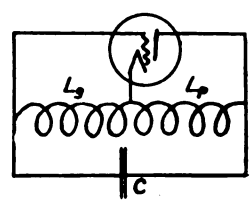


FIG. 2—HARTLEY CIRCUIT

The separate source of power used is generally direct current. It is not necessarily so as alternating current, can be used if a single continuous frequency is not necessary. The power represented by the oscillation current all comes from the direct-current source. The oscillator acts only as a frequency changer, changing the power from zero frequency to that delivered into the oscillation circuit.

4. THE SIMPLE OSCILLATOR CIRCUIT

The two simplest types of oscillator circuits are shown in Figs. 1 and 2. They differ in a few points only. In Fig. 1 the oscillation circuit is $L_g\,C$ and the coupling to the plate circuit is the mutual inductance between L_p and L_g. In Fig. 2 the oscillation circuit is $(L_g + L_p)\,C$, and the coupling to the plate is the self inductance of L_p. Of the two circuits the former appears logically to be the simpler and more fundamental and the latter only a special case of it. Actually the latter is met with more often in practise. This is due to the inherent construction of the audion. If the audion were strictly a unilateral electrical device, a condition it approaches at low frequencies, the circuit in Fig. 1 would unquestionably be considered the fundamental circuit. Actually, however, the inherent capacity between the plate and grid prevents us from obtaining this desired condition, and in many cases causes oscillators to behave according to the circuit in Fig. 2 instead of according to the circuit in Fig. 1. For this reason, Fig. 2 is considered the simpler of the two and will be discussed first.

The number of oscillator circuits possible is innumerable. They can, however, all be resolved into one of the simple circuits of the types shown in Fig. 1 or 2, by considering the elements L_p, L_g or C as being made up of complex circuits instead of simple inductances or capacities. The actual operation of the simple circuits can be shown in detail while for the more complex circuits, which do not lend themselves readily to mathematical analysis, the operation can be quite easily explained by resolving them into equivalent simple circuits and applying the theory of operation of the latter.

The simple Hartley oscillator in Fig. 2 will be explained first. The circuit as shown contains only the alternating current elements. The direct-current branches necessary to its operation may be brought in in a number of ways by inserting proper choke coils and condensers to keep the d-c. and a-c. paths separate. We are interested only in the a-c. operation at present and will therefore show only the necessary parts of the circuit.

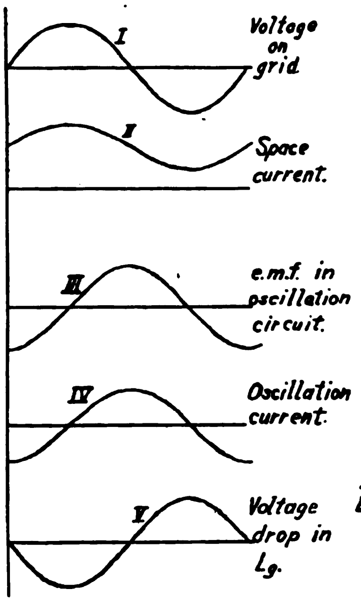
The frequency in this oscillator is determined by the oscillation circuit $(L_p + L_g + 2\,M)\,C$. The resistance, audion output impedance, and amplification constant affect the frequency slightly, but it is mainly the reactance of the oscillation circuit which determines the frequency. The inductances L_p and L_g may be of approximately equal value with or without mutual inductance. The condenser is connected directly between the grid and plate and includes the capacity between these elements.

A simple explanation of how and why the oscillations occur is as follows:

Assume to begin with, that in some manner an alternating voltage is impressed upon the grid. Such a voltage will cause an alternating current to flow in the plate circuit. This plate alternating current must flow through the inductance L_p or through L_g and C, or divide between these paths. The result is the same whatever path is taken, but for the purpose of a simple explanation it will be assumed that it all flows through L_p. In flowing through L_p this alternating space current produces an alternating e. m. f. This alternating voltage is the driving e. m. f. in the oscillation circuit and causes the oscillation current to flow. In flowing through L_g the oscillation current produces an inductive voltage drop which because of the connection of the grid, is applied between the grid and the filament. This is the alternating voltage assumed to begin with as being applied to the grid.

The operation of the oscillator is thus a cyclic one and is continuous and self sustaining as long as direct current is supplied to the audion to make the

plate circuit a two-way conductor for variable currents. The operation of the oscillator may be compared to a steam engine with the grid controlling the flow of electricity exactly as the slide valve controls the flow of steam. The alternating potential on the grid produces an alternating current in the plate circuit just as the slide valve causes steam to move the piston back and forth in the cylinder. The alternating space current produces a large oscillation current in the oscillation circuit just as the piston produces a rotary motion of the driving shaft. The oscillation current in producing the original grid alternating potential by passing through L_g, corresponds to the rotating shaft producing the original to and fro slide-valve motion by means of the eccentric. The cyclic action in both is continuous and self-sustaining. The analogy, however,



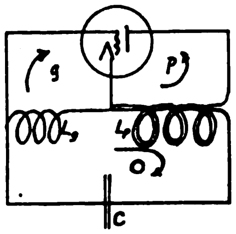


Fig. 3—Hartley Circuit Approximation

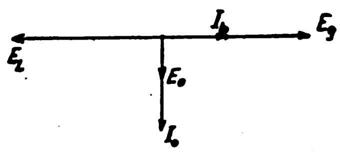


Fig. 4—Phase Relations in Hartley Circuit

Fig. 5—Vector Diagram of Phase Relations

falls down in that the frequency in the audion oscillator is determined by the circuit, while the steam engine it is determined by the load and steam pressure.

In explaining the phase relations in an oscillator, the resistance will at first be assumed as zero and the circuit as shown in Fig. 3. L_p is shown drawn in two parts to make the paths of the alternating space current and oscillation current separate. This circuit consists of three meshes or complete circuits, grid, plate, and oscillation. They are indicated by the letters g, p, and o. Positive-current directions are assumed in each circuit and are indicated by arrows. The directions in the grid and plate circuits are so chosen that a positive voltage in the grid circuit (which raises the grid potential) causes a positive current to flow in the plate circuit. An increase in the grid potential of an audion causes the space current to increase, and with the direction assumed in the plate circuit as positive, the increase in space current is a positive current. When a positive current flows through inductance L_p it is flowing through an element which is also part of the oscillation circuit and the direction assumed as positive in the oscillation circuit is such that the positive plate current is also a positive current in the oscillation circuit. When a positive oscillation current flows through inductance L_g it flows through an element which also belongs to the grid circuit. A current flowing through L_g in the direction indicated by the oscillation circuit arrow is a positive oscillation current but when referred to the arrow in the grid circuit, it is a *negative* current. The current although flowing in the direction of the arrow in one circuit flows in the opposite direction to the arrow of the other circuit. This must be kept in mind in the following description because it means that a voltage or current in L_g which is positive while considered as in the oscillation circuit is negative when considered as in the grid circuit and vice versa. This means that an alternating voltage or current in the oscillation circuit must be given a 180 deg. shift, or reversed, if we wish to talk about it in the grid circuit.

In Fig. 4, Curve *I* represents the alternating voltage applied between the grid and the filament. This voltage causes the alternating space current, Curve *II* to flow. In flowing through L_p the alternating space current produces an e. m. f. 90 degrees behind it (shown in Curve *III*). This in turn produces an oscillation current (Curve *IV*) which is in phase with it on account of the frequency being the resonant frequency. The oscillation current in flowing through L_g produces an e. m. f. 90 degrees out of phase (Curve *V*). This e. m. f. transferred to the grid mesh of which it is a part must be given an opposite sign (for reasons stated before) and it is then observed to be the original voltage applied to grid.

6. Simple Vector Diagram

The phase relations are shown in vector form in Fig. 5. The grid voltage is E_g. The alternating space current is I_b. The voltage produced in L_p by I_b is E_o and this produces the oscillation current I_o. The latter in flowing through inductance L_g produces the voltage drop E_L. This because of oppositely assumed positive directions in meshes g and o must be reversed and is the grid voltage E_g.

7. Vector Diagram Including Resistance

In previous explanations the assumptions were made that the oscillation circuit resistance was zero, and that all the plate alternating current passed through the inductance L_p. To show the relations in the actual circuit it is preferable to arrange the circuit as shown in Fig. 6 with the positive directions in the branches (instead of in the circuits) indicated by the arrows. The plate and grid inductances are assumed to have no mutual between them, and each element of the oscillation circuit has its own resistance.

The elements of the oscillation circuit as arranged

are called the external circuit to distinguish them from the internal circuit of the audion. Such an arrangement of inductances and capacity has a reactance—frequency curve, as measured between the points connected to the plate and filament, of the form shown in Fig. 7. The resonant frequency for the oscillation circuit as a series circuit occurs at "r" which is at or near the point at which the reactance of the parallel arrangement changes sign. The frequency of oscillation in this type of circuit always occurs just below the resonant frequency on account of the resistance in the circuit elements. This has been observed experi-

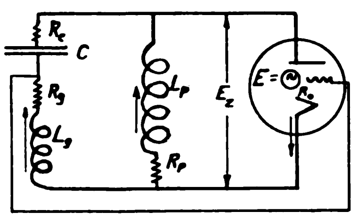


FIG. 6—RE-ARRANGEMENT OF HARTLEY CIRCUIT SHOWING POSITIVE DIRECTIONS ASSUMED IN VARIOUS BRANCHES

mentally and shown analytically, and can be proved by the vector diagrams. The external circuit will therefore have an inductive reactance when attached to the audion as an oscillator. The circuit is looked upon as an external circuit in series with an audion which contains a fictitious generator of voltage E and internal resistance R_o. The voltage of the fictitious generator is μE_g where E_g is the voltage applied between grid and filament and μ is the amplification constant of the audion.[2].

In Fig. 8, the voltage applied to the grid is E_g. The fictitious plate circuit generator voltage is then

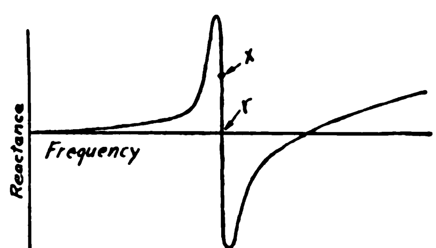


FIG. 7—REACTANCE OF EXTERNAL CIRCUIT OF FIG. 6 AS A FUNCTION OF FREQUENCY

$E = \mu E_g$ and is in phase. Due to the inductive reactance of the external circuit, the alternating space current I_b lags. The alternating space current in flowing through the external circuit produces a resistance drop $I_b R$, where R is the external resistance, and a reactance drop of $I_b X$, where X is the external resistance. Attention is here called to the fact that voltage drop $I_b R$ is *opposite* to the direction in which I_b flows, and $I_b X$ is 90 deg. *behind* I_b. This is not according to a conventional method used by some engineers but it agrees strictly with Faraday's law of the sum of the e. m. f. in a closed circuit being zero. The two counter e. m. fs. produced by I_b add up into the external counter e. m. f., or drop, E_d, an e. m. f. produced entirely by I_b. Equal and opposite to E_d is the e. m. f. E_z which is that part of E which is consumed by E_d. Within the audion I_b produces another resistance drop E_a also opposite in direction to I_b. E_a added to $I_b R$ and $I_b X$ produce a counter e. m. f. equal and opposite to E making the sum of the e. m. fs. in the circuit zero. The voltage applied to, and across the external circuit is then E_z which is equal and opposite to the external drop E_d. It is the driving voltage for the external circuit. The external driving voltage applied across inductance L_p causes a lagging current I_p (Fig. 9) to flow. It is less than 90 deg. behind E_z because of resistance in L_p. E_z also causes a leading current to flow through the other arm $C + L_g$ which is almost 90 deg. ahead (I_g). The sum of the two currents is I_b the alternating space current. I_p is larger than I_g because the operating frequency is below the resonant value and the inductive reactance of L_p

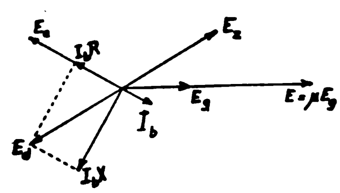


FIG. 8—VECTOR RELATIONS IN THE HARTLEY CIRCUIT

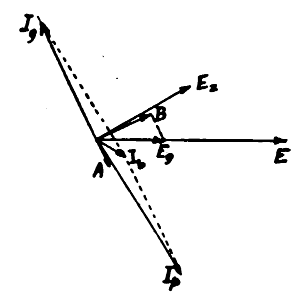


FIG. 9—VECTOR RELATIONS IN THE HARTLEY CIRCUIT

will then be less than the capacitive reactance of $C + L_g$. The current I_g in flowing through the inductance L_g produces a resistance drop A and a reactance drop B. The sum of these is E_g the voltage applied to the grid.

The impossibility of this circuit operating above resonance can be shown from Fig. 9. The grid voltage E_g must always be in phase with E as $E = \mu E_g$. E_g is the vector sum of A and B which are voltage drops in L_g. I_g will be just 90 deg. ahead of E_g if the resistance of L_g is zero, but any resistance in L_g produces the drop A and I_g is forced more than 90 deg. ahead of E_g. Then, as I_g is a leading current produced by E_z it can be 90 deg. ahead of E_z if the total resistance in C and L_g is zero, but with resistance the angle is reduced and E_z must be moved closer to it and ahead of E_g. Stated in a few words we can say: (1) the angle between E_g and I_g must always be over 90 deg., (2) the angle between I_g and E_z must always be less than 90 deg., therefore E_z must always be ahead of E_g and E which means an external circuit of inductive reactance and (from Fig. 7) a frequency below resonance.

2. Nichols, *Physical Review*, August 1917 and June 1919.

8. Vector Diagram with Mutual Inductance Between L_p and L_g

Fig. 10 is a vector diagram like that in Fig. 9 as regards voltages, currents and notation. If there is mutual inductance between L_p and L_g, the current in L_p produces an e. m. f. in L_g which is either e_1 or e_2 depending upon whether the mutual inductance is negative or positive. By a positive inductance is meant a coupling such as to make the total inductance in the oscillation circuit greater—that is $L_o = L_p + L_g + 2M$.

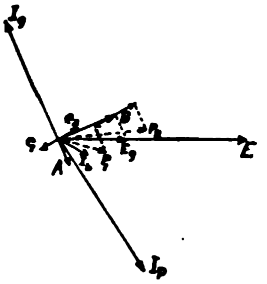


Fig. 10 — Influence of Mutual Inductance Upon Phase Relations

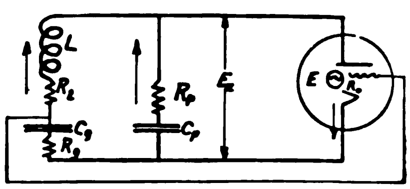


Fig. 11 — Re-Arrangement of Colpitts Circuit Showing Positive Directions Assumed in Various Branches

If the mutual is positive I_p produces the e. m. f. e_2 which when added with A to B produces the vector P_2 as the grid voltage. This position cannot obtain as the grid voltage must be in phase with E. To get this, all vectors except E must rotate slightly to the right which means that the external inductive reactance is smaller in proportion to the resistance and that the frequency is nearer the resonant frequency. If the mutual inductance is negative, I_p produces the e. m. f. e_1 in L_g and it with A added to B produces the vector P_1 for the grid voltage. For P_1 to coincide with E, all vectors except E must rotate to the left. A negative mutual inductance reduces the voltage applied to the grid, and increases the external reactance, thereby causing the oscillation frequency to drop farther below the resonant frequency. A negative mutual inductance makes the oscillator less likely to oscillate than a positive value.

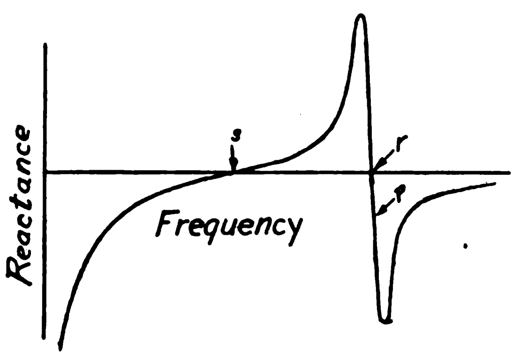


Fig. 12—Reactance-Frequency Curve for External Circuit in Fig. 11

9. Phase Relations in the Colpitts Circuit

The Colpitts oscillator circuit is shown in Fig. 11. It is drawn in a similar manner to the Hartley circuit in Fig. 6. The external circuit in this case consists of C_p in parallel with a series circuit consisting of L and C_g. The reactance-frequency curve of this type of circuit is given in Fig. 12. The resonant frequency of the oscillation circuit (C_p, C_g and L) is at or near the point marked "r." The reactance of the combination passes through zero at S due to L and C_g resonating at that frequency. The frequency at which oscillations occur, however, will be around "r" which is the resonant frequency of the oscillation circuit.

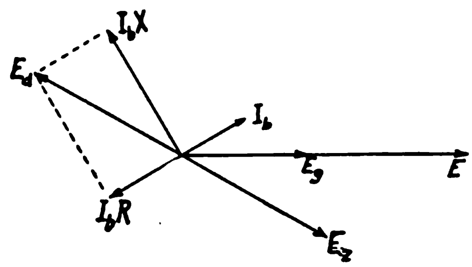


Fig. 13—Phase Relations in Colpitts Circuit

Mathematical analysis and experimental observation show that in this circuit the frequency of oscillation is above resonance. The external circuit will therefore have capacitive reactance. If E_g is the grid voltage, Fig. 13, and E the fictitious generator voltage, the alternating space current I_b will lead. The drop across the external resistance will be, $I_b R$, and across the external resistance, $I_b X$. The external drop will be E_d, or reversing E_d into E_z we have that part of the voltage E which is applied to the external circuit. The voltage E_z which is thus the driving voltage for the external circuit sends a leading current I_p Fig. 14 through condenser C_p and a lagging current I_g through condenser C_g and inductance L. Due to operating above resonance, the former will be a trifle the greater. The sum of the two is the alternating space current. The angles of E_z with these currents is slightly under 90 deg. due to resistance. The lagging current I_g in flowing through condenser C_g produces a resistance

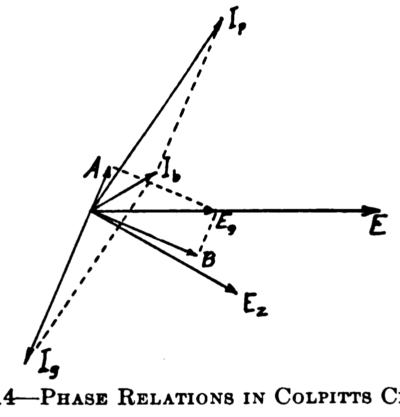


Fig. 14—Phase Relations in Colpitts Circuit

drop A and a reactance drop B the sum of which, E_g, is applied to the grid.

The oscillation frequency in this circuit must always be above the resonant frequency. The angle between E_g and I_g must always be 90 deg. or greater and that between E_s and I_g must always be 90 deg. or less. This means E_s must always be behind E_g (or in phase if resistances are zero), and can never be ahead. To produce this relation of E_s and E_g, the external circuit must always have capacitive reactance which, from Fig. 12, is observed to occur at a frequency above the resonant frequency.

In the Hartley circuit, inserting resistance in any part of the oscillation circuit lowers the frequency. In the Colpitts circuit, inserting resistance in series with C_g raises the frequency, because it increases the voltage drop A thereby rotating B to the right (E_g being fixed) and therefore I_g (90 deg. from it) to the right. Although increasing the resistance of C_g reduces the angle between I_g and E_s, the reduction is smaller in amount

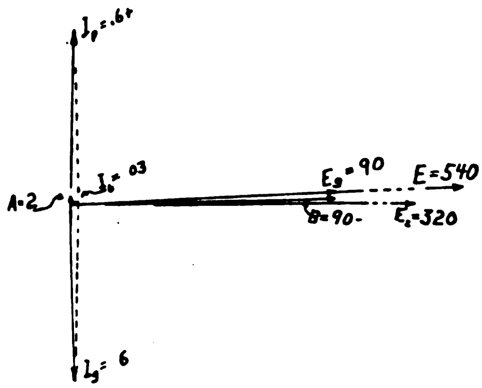


Fig. 15—Actual Current and Voltage Relations and Values in a Typical Colpitts Circuit

than the increase between I_g and E_g. The angle between E_g and I_g depends upon two resistances in series, (R_L and R_g) and the inductive and capacitive reactance, while that between I_g and E_g depends on R_g and the capacitive reactance alone. The values used are such that the variation, by R_g, of the $E_g - I_g$ angle, is greater than the $E_s - I_g$ angle, and E_s must rotate to the right if R_g is increased. E_s will rotate to the right only if the external reactance increases which will occur (from Fig. 12) only if the frequency is raised.

Increasing the resistance of L reduces I_g, and reduces the angle between it and E_s. As the change in amplitude of I_g will be small, the principal change will be a shift of I_g toward E_g. If the reduction in the angle between E_s and I_g is greater than the reduction in the angle between E_g and I_g, E_s will move to the right which means more capacitive reactance and a higher frequency. If the shifts are the reverse in relative amounts, the frequency will be reduced. Both can occur under certain conditions. In a mathematical analysis, the equations given for this circuit[3] indicate

3. In the course of publication.

that the frequency rises if the resistance of L is increased. In highly oscillatory circuits where the top and bottom of the characteristic curve are reached, a reduction in frequency has been observed.

Increasing R_p reduces the $E_s - I_p$ angle, and although this reduces I_p, it may increase I_b. It shifts I_b toward E which means less external capacitive reactance,—a condition which occurs only if the frequency is reduced (see Fig. 12 where p is the oscillation point).

10. The Ordinary Feed-Back Circuit

In the ordinary feed-back circuit Fig. 1 the frequency is determined by L_g C as the oscillation circuit. Power

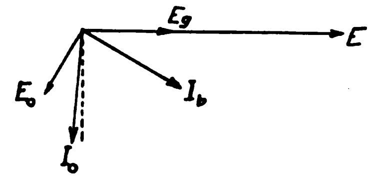


Fig. 16—Phase Relations in Feed-Back Circuit with Loose Coupling

is delivered to this circuit by the mutual inductance between L_g and L_p. The phase relations are indicated in Figs. 16 and 17.

This circuit can operate either above or below the resonant frequency of the oscillation circuit according as the coupling betwen L_p and L_g is tight or loose. Fig. 16 shows the vector diagram for the condition of loose coupling. E_g is the grid voltage and E is the fictitious generator voltage. The space current I_b lags, due to the inductance in the plate circuit. I_b produces, in L_g, the voltage E_o 90 deg. behind it. Due to operating below resonance, the reactance of the oscillation circuit is capacitive and the oscillation

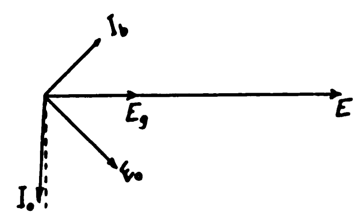


Fig. 17—Phase Relations in Feed-Back Circuit with Tight Coupling

current I_o will lead E_o. I_o in passing through C produces the grid voltage E_g, 90 deg. or more ahead of it, according as its resistance is zero or finite. In any case, the angle between I_0 and E_g is very close to 90 deg., as the resistance is always very small in comparison to the reactance.

The alternating space current I_b lags behind E on account of inductance from two sources, the inductance of L_p and the inductance introduced into L_p by its coupling with L_g. An equation will be given in a following paragraph (equation 6) showing that when the reactance in the secondary is capacitive, the reactance introduced into the primary is inductive and

vice versa. This makes I_b lag further behind E than would be the case if the only reactance were that of L_p.

Fig. 17 shows the vector diagram for the condition of tight coupling and the frequency above resonance. E_g and E have the usual meanings. The external capacitive reactance causes the alternating space current I_b, to be ahead of E. I_b produces in L_g the driving oscillation current voltage E_o, which in turn produces the oscillation current I_o. Due to operating above resonance, the oscillation circuit reactance is inductive, and I_o will lag behind E_o. I_o in turn

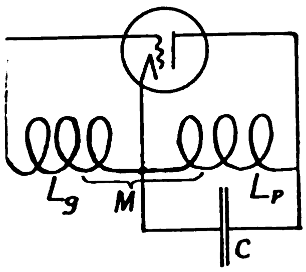


Fig. 18—Reversed Feed-Back Circuit

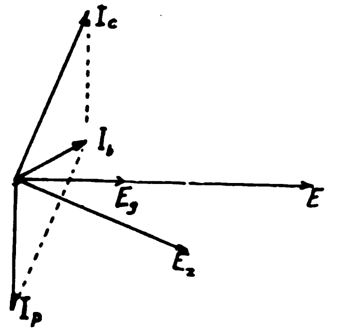


Fig. 19—Phase Relations in Reversed Feed-Back Circuit. Resistance only in L_p

produces E_g 90 deg. or more ahead, due to the reactance of condenser C.

The alternating space current leads E because of the external capacitive reactance. L_p has inductive reactance but because of close coupling there is introduced, from the secondary with its inductive reactance, more capacitive reactance than sufficient to neutralize the reactance of L_p. The resultant reactance becomes capacitive.

In the case of the loose coupling and lower than resonant frequency, the introduction of resistance into the oscillation circuit causes a lowering of the frequency. In the case of the tight coupling and higher than resonant frequency, increasing the resistance raises the frequency.

This type of circuit has still another form of action which will be explained later (section 16).

11. Reversed Feed-Back Circuit

The reversed feed-back circuit is the same in form as the feed-back circuit, but with the grid and plate connections interchanged, Fig. 18. The interchange of grid and plate connections does not affect its ability to oscillate, except in the region of feeble oscillations, when it may oscillate with one connection but not with the other.

The vector diagram is given in Fig. 19. The frequency, in this circuit, is always above the resonant value for the oscillation circuit. The external plate circuit will therefore have capacitive reactance, and I_b will lead E and E_z. E_z (the part of E consumed by the external circuit) sends a lagging current through L_p and a leading current through C. Suppose at first that the resistance is all in L_p. L_p will then be less than 90 deg. behind E_z, and I_c will be 90 deg. ahead. The voltage E_g, produced in L_g by mutual inductance with L_p, must always be 90 deg. ahead of I_p, as there are no drops occurring in the grid circuit. With the $E_g - I_p$ angle 90 deg., and the $E_z - I_p$ angle less than 90 deg., E_z must be behind E_g and E, a condition which can occur only if the external circuit reactance is capacitive. This condition occurs in a parallel resonant circuit when the frequency is above resonance.

If the resistance is all in C, I_p will be just 90 deg. behind E_z and E_g will be 90 deg. ahead of I_p Fig. 20. E_z will coincide with E_g and E, and the external circuit will have no reactance. I_c will be less than 90 deg. ahead of E_z and when added to I_p will produce I_b in phase with E. A parallel resonant circuit has capacitive reactance at the resonant frequency if the resistance is largely in the inductance, or inductive reactance if the resistance is largely in the capacity. In this case the resistance is largely in the capacity and at resonance would give inductive reactance. Since the vector diagram requires the reactance to be zero, the frequency must be above resonance a sufficient amount to produce this condition. This circuit will therefore never operate below resonance, and will operate at resonance only if the oscillation circuit resistance is zero.

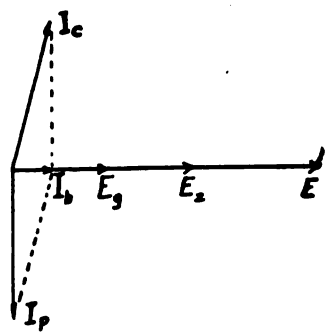


Fig. 20—Phase Relations in Reversed Feed-Back Circuit. Resistance only in C

12. Qualifying Approximation

These vector diagrams are all based upon the assumption that the grid-plate-filament capacities may be neglected, and that no current flows to the audion grid. The former is true only for the lower frequencies, and the latter depends upon the construction of the circuit. In practise, the pronounced effects discussed have been observed while the slight effects have been difficult to observe and sometimes reversed on account of the factors neglected.

A second factor, which makes the smaller effects hard to observe, is the fact that the audion does not behave strictly in the manner assumed (constant resistance plus an enclosed generator with a sine e. m. f.). The fictitious generator e. m. f. contains innumerable harmonics which are not constant, but

which change their amplitude and phase with changes in the external circuit. In certain adjustments of the circuits, the audion acts more like a shock exciter for a tuned circuit than as a continuous alternating-current generator. The addition of resistance to a tuned circuit lowers the natural frequency, and occasionally, such a lowering is observed in the audion oscillator when no change, or a rising is expected. The failure of observed results and theory to agree only occurs for second order effects and indicates that the vector diagrams do not show exactly the actual action,

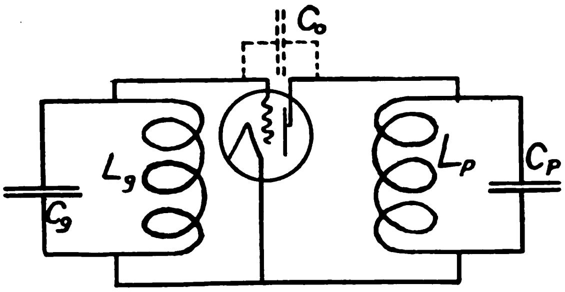


Fig. 21—Amplifier of Type Oscillator Circuit

due to the assumption of a constant output audion impedance instead of a variable one.

13. Determination of Frequency

The frequency of oscillation is always determined by the oscillation circuit. In few if any cases is the frequency actually the resonant frequency but in all cases it is very close to that value. The resistance of the elements, leakage reactance etc., cause phase shifts which produce a shift in frequency to meet the requirements. In general, the difference between the actual and resonant frequencies is not over one per cent.

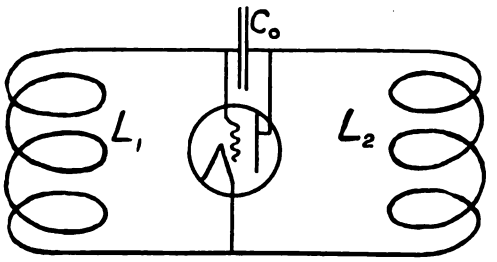


Fig. 22—Elementary Hartley Circuit Without Mutual Inductance

In order that a circuit of any frequency may produce an alternating current without a driving alternating voltage, it is necessary that the impedance be zero. This means that both the resistance and reactance must be zero. The production of zero resistance in an audion oscillator is dependent upon the values of the constants of the various elements in the circuit, while the production of zero reactance is only a question of the proper frequency. An audion oscillator circuit has reactance at all frequencies but one, or two etc., as the case may be. It is obvious then that if the construction of the oscillator is such that the resistance is zero for quite a range of frequencies, but the reactance is zero for only one frequency, that that one frequency will be the one which will occur without a driving e. m. f. The condition of the reactance being zero is thus the criterion of the frequency of oscillation.

The reactance of an oscillator circuit is largely dependent upon inductance and capacity, but like all coupled circuits it is also affected by resistance in the various parts. The output impedance of the audion, and the amplification constant also, affect it somewhat, but the major influence is inductance and capacity. For qualitative work it is sufficient to consider the reactance as produced by these elements only and satisfactory results are obtained.

14. Application to Complex Circuits

The determination of the behavior of a complex circuit like that of Fig. 21, can easily be made qualitatively by the application of the simple circuit theory, and quantitatively with a little more difficulty. The circuit as indicated has two tuned circuits with no

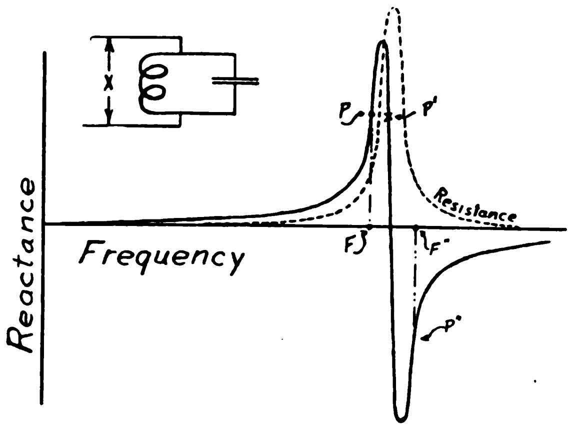


Fig. 23—Effective Reactance and Resistance of a Parallel Resonant Circuit

mutual reactance between the coils. The grid-plate capacity is an important part of this circuit and is indicated by C_o. The circuit combinations in the plate and grid circuits are to be represented by single elements to form a simple Hartley circuit Fig. 22. If C_p L_p and C_g L_g are tuned to the same frequency (and for simplicity in explanation have equal values throughout) the reactance curve in Fig. 23 can represent the reactance of either parallel combination, as a function of frequency. The frequency with which this circuit operates is that at which the reactance in the oscillation circuit indicated by Fig. 22 is zero. That is, C_p and L_p, in parallel, act as inductance L_2 and C_g and L_g in parallel act as inductance L_1. The values of L_1 and L_2 are to be taken from Fig. 23 and are markedly dependent upon the frequency. If the frequency of oscillation is F Fig. 23 the effective reactance of L_1 (C_g and L_g in parallel) is indicated by the point P on the curve, and the reactance of L_2 is the same. The sum of these reactances must equal the capacitive reactance of C_o at the frequency F. If the frequency of oscillation

should momentarily be less than F, the reactance of L_1 and L_2 would be so low that, with C_o the natural frequency would be higher than F and the frequency would rise. If it should be higher than F momentarily, the inductive reactances would be so high that, with C_o, the natural frequency would be lower than F, and the frequency would fall. The stable frequency point is that at which there is produced sufficient reactance in L_1 and L_2 to make the reactance, with C_o equal to zero.

It will be observed that at the point P' in Fig. 23 the same conditions of effective inductance and zero reactance occur. However, oscillations never occur at that point because it is unstable. Any reduction in frequency increases L_1 and L_2, which further reduces

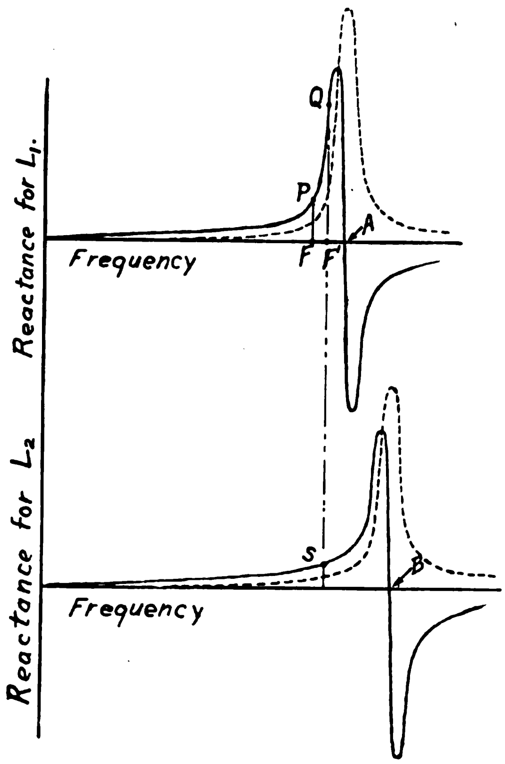


Fig. 24—Effective Resistance for L_1 and L_2 when Circuits are Tuned to Different Frequencies

the frequency, and it moves over the curve until the point P is reached.

The frequency of oscillation is thus never the natural frequency of either tuned circuit but is always lower. It always falls on the low frequency side of the inductive reactance hump for the parallel resonant circuit. If the two circuits are tuned to different frequencies, the frequency of oscillation will always be lower than the lower of the two. If $C_g\, L_g$ (producing L_1) is tuned to frequency A in Fig. 24, and $C_p\, L_p$ (producing L_2) is tuned to frequency B, the frequency of oscillation will always be lower than A. If both circuits are tuned to A, the oscillation frequency is F, giving $\omega L_1 = \omega L_2 = P$, but if $C_p\, L_p$ is tuned to B, the frequency rises from F to F' for at the latter frequency the reactance of $L_1\ (= Q)$ plus $L_2\ (= S)$ is equal to the capacitive reactance of C_o at frequency F'. If frequency B is so much higher than A that no sum of $Q + S$ can equal $\frac{1}{2\,\pi\, F'\, C_o}$ the oscillations will cease, or if the ratio of Q to S (L_1 to L_2) does not satisfy the required conditions for oscillation in the simple circuit, oscillations will cease. This latter failure may be caused by the effective resistance of one of the parallel circuits rising to such a value at F' (see dotted line in Fig. 24) that oscillations are stopped.

The influence of C_o upon the frequency is not large.

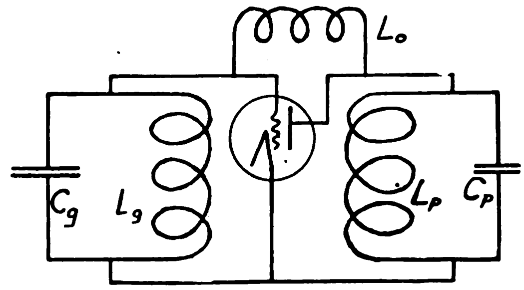


Fig. 25—Modified Amplifier Type Oscillator Circuit

Quadrupling C_o may reduce the frequency less than 10 per cent. The reason for that is that the slope of the reactance curve in the region of operation is so great that a reduction of 10 per cent in frequency will reduce the reactance 75 per cent and the new reactance will equal the reactance of the quadrupled C_o at the new frequency.

An interesting fact concerning this general type of oscillator is that by a certain modification it can be made to oscillate above the resonance point of the two tuned circuits. In the circuit as just discussed, there was capacity between the grid and plate. The parallel

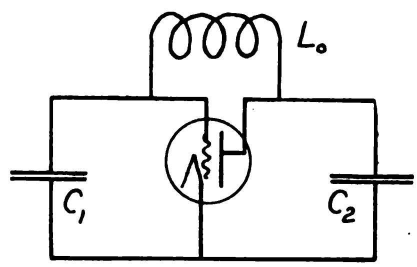


Fig. 26—Equivalent of Circuit in Fig. 39

resonant circuits then operated as inductances producing the equivalent of a Hartley circuit. If the reactance between the plate and grid can be made inductive, instead of capacitive, such as by connecting an inductance (L_o in Fig. 25), the parallel resonant circuits will then act as capacities (C_1 and C_2 in Fig. 26), and produce a Colpitts type of oscillator. The frequency of oscillation F'' will in this case be above resonance giving the capacitive reactance P'' in Fig. 23. The condition of oscillation in this arrangement is similar to that of the previous one—the sum of the capacitive reactances of the grid and plate parallel resonant circuits

will be equal to the inductive reactance of L_o at the operating frequency F''. The frequency of oscillation in this circuit is likewise never the resonant frequency of either tuned circuit but is above that of the higher of the two. It is always on the high frequency side of the capacitive reactance hump and never on the unstable lower side.

Fig. 27 shows the nature of the behavior of the oscillators. The ordinate is the frequency of oscillation and the abscissa, the natural frequency circuit $L_g C_g$. The plate circuit $L_p C_p$ was kept set at 455,000 cycles throughout. The circles at the ends of the curves mean that oscillations ceased at those points. It will be observed that conditions mentioned before, hold—that with capacity between grid and plate, the frequency always remains below the resonant frequency of the lower circuit, and with inductance between the grid and plate the frequency is always above the higher. The small change in frequency produced by multiplying C_o by 4 can also be observed.

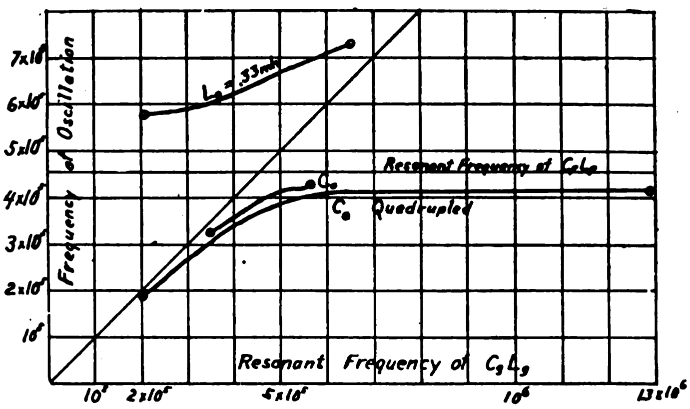


FIG. 27—FREQUENCY BEHAVIOR OF AMPLIFIER TYPE OSCILLATOR

The "singing" of amplifiers comes under the head of this type of circuit. By "singing" is meant the oscillating of a circuit when it is not desired that such circuit should oscillate. The repeating coils connected to the plate and grid always have distributed capacity and form a circuit similar to that shown in Fig. 21. The stabilizing of the circuit is accomplished in several ways. Additional capacity can be placed across the transformer thus throwing its resonant point far enough to one side to prevent oscillations. Resistance may be placed across the other windings of one transformer thus changing both the resistance and the inductance and throwing the circuit into the non-oscillatory state by the detuning and the introduction of resistance. Resistance may be placed across the side of the transformer connected to the audion thus changing the effective reactance and resistance. Other slight modifications can be used which come under the head of detuning one circuit or increasing the effective resistance at the troublesome frequency.

15. COUPLED CIRCUITS

When an oscillator is constructed having an oscillation circuit with two degrees of freedom, oscillations will occur at one or both frequencies. The Meissner circuit, Fig. 28, is a coupled circuit oscillator having two tuned circuits $(L_g + L_p)\, C_o$ and $(L_2 + L_3)\, C_2$. The determining condition for free oscillations, in any case, is that the total reactance in the circuit attached to the audion shall be zero. In Fig. 29, X is the curve of reactance of the primary circuit $(L_p + L_g)\, C_o$ above. The curve W is the reactance introduced into the primary oscillation circuit by the mutual inductance between it and the secondary oscillation circuit $(L_2 + L_3)\, C_2$.

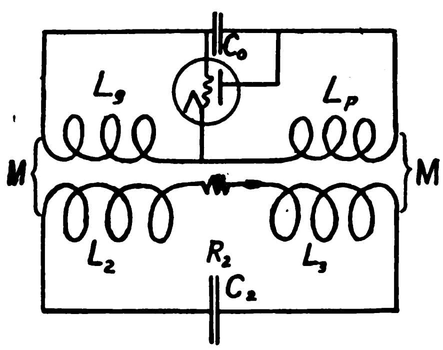


FIG. 28—A SIMPLE COUPLED CIRCUIT

This reactance is expressed by the formula

$$W = - \frac{M^2 \omega^2 \left[(L_2 + L_3)\, \omega - \dfrac{1}{\omega C_2} \right]}{R_2^2 + \left[(L_2 + L_3)\, \omega - \dfrac{1}{\omega C_2} \right]^2} \qquad (1)$$

The total reactance in the primary circuit will then be the sum of the self and introduced reactances, as given by Z in the same figure. It is assumed in this case that the two circuits are tuned to the same frequency, F. The frequencies at which the oscillations will occur will be those at which the total primary reactance is zero;

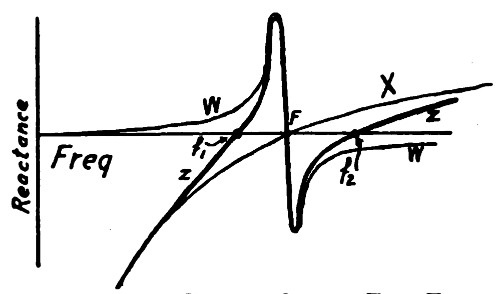


FIG. 29—REACTANCE CURVES GIVING TWO FREQUENCIES

f_1 and f_2 in Fig. 29. The reactance is also zero for frequency F but that is an unstable point, and any oscillations starting will move over to frequencies f_1 or f_2.

It is an experimental fact that in oscillators of this kind adjusted for maximum power, or thereabouts, oscillations occur at only one of the two possible frequencies at one time, but by suitably manipulating the circuit the oscillation frequency can be either one or the other as desired. Oscillations at both frequencies simultaneously would occur if the characteristic curve were an indefinite straight line and in all prob-

ability do occur when the starting switch is closed and the oscillations are building up. However, the relative inductive and capacitive reactances and resistances are never the same for the two frequencies and one may build up faster than the other when starting. When once oscillating fully the top and bottom to the characteristic curve prevent the proper supply of power being delivered during the additive part of the beats, and one of the oscillations is likely to die out. Such behavior also occurs in circuits coupled to arcs, there being similar limits in the arc characteristic

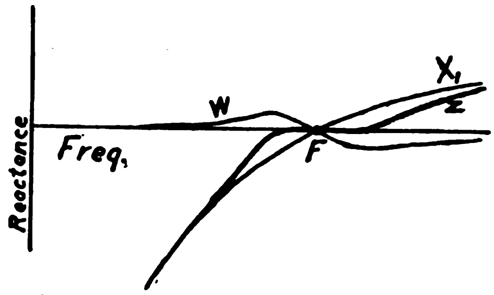


Fig. 30—Reactance Curves when Adjusted for Limiting Condition Between One and Two Frequencies

which allow oscillations at only one frequency at a time.

In coupled circuits so constructed, opening or closing a switch, or momentary changes in any other part of the circuit, can make the frequency change from one natural frequency to the other, or back. Drawing power out of the oscillator at one frequency is likely to stop it oscillating at that frequency, whereupon it immediately starts up at the other.

It is possible to so construct this type of circuit that only one oscillation will occur under any condition.

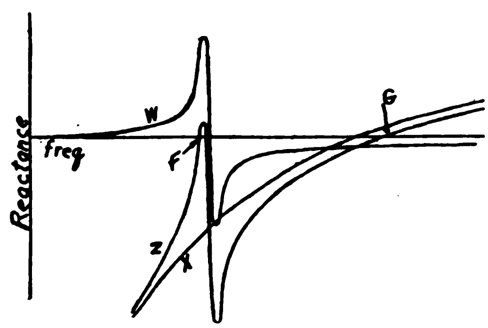


Fig. 31—Reactance Curves for a Coupled Circuit Likely to Give but a Single Frequency

If the two circuits are tuned to the same frequency but are constructed so that

$$M^2 < L_1 C_2 R_2^2 \qquad (2)$$

where $L_1 = L_p + L_g$, the reactance introduced (W) will be such as to produce only one intercept for Z. The curves indicating the primary oscillation circuit reactance X_1, the introduced reactance W, and the resulting reactance Z, are shown in Fig. 30. The above expression gives a critical value a trifle too high, for if $M^2 = L_1 C_2 R_2^2$ there are still three intercepts but they are close together and a slight reduction in M makes them merge into one. This expression was derived by equating the slope of the primary oscillation reactance curve to the negative slope of the introduced reactance curve W at the resonant value. Thus by constructing this type of circuit with two circuits tuned to the same frequency, and such that the primary one has a large ratio of L_1 to C_o, or the secondary one has a small ratio of $(L_2 + L_3)$ to C_2, a single frequency circuit can be obtained and full power delivered into the secondary circuit.

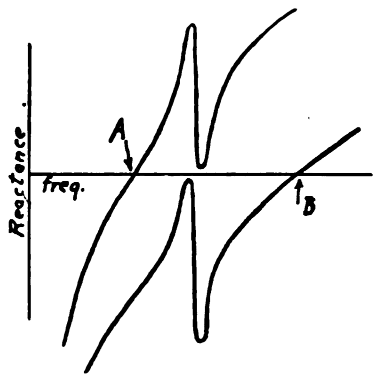


Fig. 32—Other Reactance Curves Similar to Fig. 31 Which Give Only a Single Frequency

When the two circuits are not tuned to the same frequency, it is comparatively easy to cause oscillations to occur at one frequency only. In Fig. 31, X stands for the reactance of the primary circuit $(L_g + L_p)\, C_o$. W stands for the reactance introduced from the secondary circuit $(L_2 + L_3)\, C_2$ which is tuned to a much lower frequency. The total primary reactance is given by Z. This gives two possible frequencies F and G, but by proper proportionment, frequency G will never occur. The effective inductances of L_g and L_p,

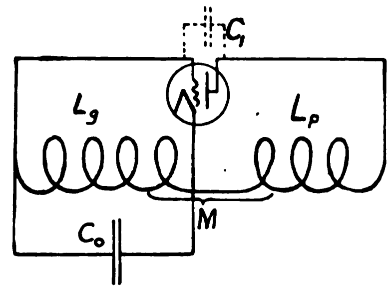


Fig. 33—A Feed-Back Circuit as it Occurs in Practise

together with the coupled tuned circuit at frequency G, are too low in comparison to the resistance and capacity C_o to allow oscillations to occur and oscillations will occur only at F.[4]

By choosing the coupling and detuning the circuits properly, reactance curves of the form in Fig. 32 can be secured. One curve has the intercept at A only and the other at B only. In one case the secondary circuit is tuned enough lower than the primary to make only one intercept real, the others being imaginary. In the other case the secondary is tuned enough higher than the primary to accomplish the same thing.

4. Due to Prof. M. K. Akers

16. Feed-back Circuits

In the previous discussion of feed-back circuits (section 10) it was mentioned that they often operated in a manner differing from that usually supposed. In Fig. 33 is shown the usual feed-back circuit with the capacity between the plate and grid represented by C_1. This circuit as shown has two tuned circuits, $L_g\,C_o$, and $(L_g + 2\,M + L_p)\,C_1$. This circuit can be resolved into the Hartley type circuit by substituting for $L_g\,C_o$

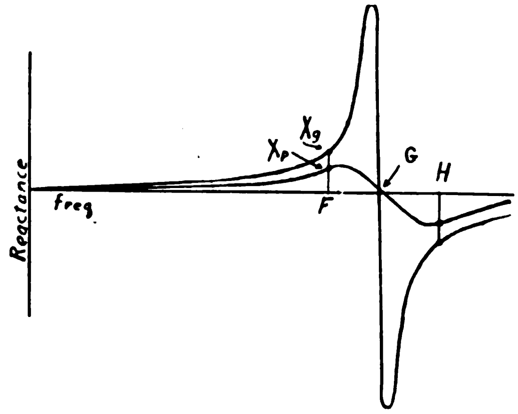


Fig. 34—Reactance Curves for Feed-Back Circuit of Fig. 33

its effective inductance, and for L_p, the effective inductance, due to its coupling with $L_g\,C_o$. Curves showing these are given in Fig. 34. The frequency of oscillation will not be the resonant frequency of $L_g\,C_o$ (G) but will be frequency F at which the effective grid and plate reactances X_g and X_p are equal to the grid-plate capacitive reactance. The frequency of oscillation will thus always be below the resonant value of $L_g\,C_o$. The behavior of the reversed feed-back circuit Fig. 18 is the same.

If this circuit has an inductive reactance between the grid and plate, such as can be produced by connecting an inductance L_o as in Fig. 25, the circuit will operate as a Colpitts circuit, above resonance. The frequency will be the value H in Fig. 34 which gives the capacitive reactance for the grid-filament and plate-filament branches.

Feed-back circuits usually operate in the manner just described when used for high frequencies. They operate in the first mentioned manner (f fixed by $L_g\,C_o$) for low frequencies. There is no sharp line of demarkation, as sometimes a circuit can be made to operate either way. It is rather a function of the values of inductances, capacities, and resistances than of frequency, but the relative capacities are to a considerable extent dependent upon the frequency.

These circuits will often oscillate in this manner when there is no mutual inductance between L_p and L_g, in which case the actual value of L_p must be sufficient to give the necessary amount of reactance X_p to make the circuit oscillate with $L_g\,C_g$ as an effective inductance, and C_1 as the capacity.

17. Direct- and Alternating-Current Branches

In drawing diagrams of oscillator circuits so far, the alternating-current parts only have been shown. This is in all cases sufficient for explanatory purposes as the direct-current paths are not all a part of the alternating-currents paths, and where not so may be omitted. In constructing any oscillator, the paths for the two kinds of current can be kept entirely separate except through the audion. It is only necessary to construct each circuit such that it does not conduct the other kind of current. In Fig. 35, the alternating- and direct-current paths of the Colpitts' oscillator are shown in which the only parts common to the two are the plate-filament and grid-filament paths of the audion, which is the minimum required in any oscillator. The alternating-current paths are broken up for direct current by the insertion of large condensers C_1 and C_2. These condensers in no way affect the frequency unless smaller than they should be made. Theoretically they should have zero reactance for the alternating current but practically they may have a reactance a few per cent, of the value of the impedance of that part of the audion with which they are in series. The direct-current paths are broken up for the alternating current by the choke coils $c\,h_1$ and $c\,h_2$. Choke coil $c\,h_2$ should have a reactance at the alternating-current frequency of several times the value of the impedance of the plate-filament path of the audion, and $c\,h_1$ should have a reactance of approximately the same value.

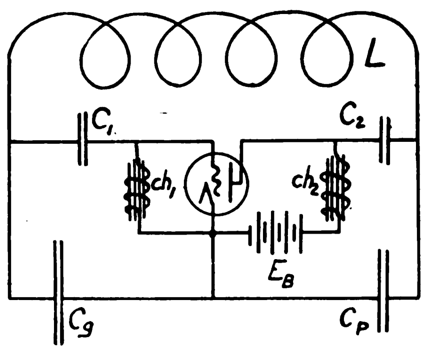


Fig. 35—Complete Colpitts Oscillator Circuit

The larger the values of these choke coils, the less will be the a-c. losses therein. Theoretically they should be infinite but practically the values mentioned before give satisfactory results. If they are large, they have no effect at all upon the frequency, but if too small, they may affect it slightly.

There are numerous other ways of constructing the direct- and alternating-current circuits, but they can all be summarized under the following: *The only common a-c. and d-c. paths required are the audion plate-filament and grid-filament paths. All external circuits solely for alternating current can have condensers inserted to prevent the flow of direct current, and all external circuits solely for direct current can have choke coils inserted to prevent the flow of alternating current. The separate a-c. and d-c. circuits must then each be properly connected to the audion.*

(To be continued.)

Economic Voltage of Long Transmission Lines

BY HENRY H. PLUMB

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THERE has been a need of a rational method of determining the economic voltage for a proposed transmission line. This voltage has often been decided upon after making several lengthy cost estimates of lines at different operating voltages. It is the purpose of this paper to indicate a solution by an application of Kelvin's Law. While this law has certain limitations, of which the engineer must be aware, attention will be called to these at the proper time. Inasmuch as a choice of line conductor is generally limited to such standard sizes as are manufactured commercially, and a choice of voltage is limited in the same way, it is neither necessary nor advisable to find a solution which is accurate to any great degree

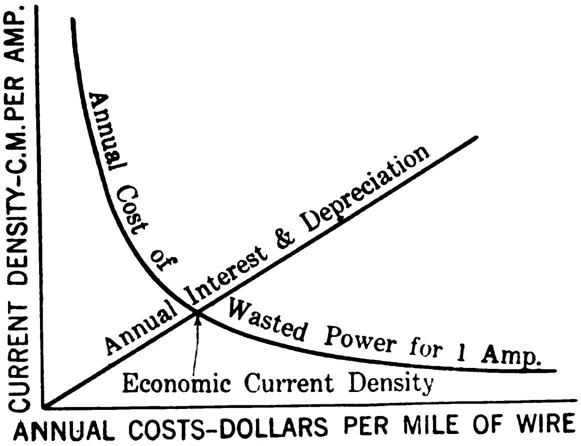

FIG. 1

of refinement. Capacity and skin effect are purposely ignored in obtaining the approximate solution. Such refinements can later be applied. The scope of this paper will be to present a rapid solution of the economic copper conductor as determined by Kelvin's Law, and using this as a stepping stone, the solution of the economic line voltage will be developed; the theory will then be extended to conductors other than copper. The principles given should be regarded as general, and should be supplemented by the use of good judgment in their application.

Kelvin's Law states that the most economical conductor is that one which gives the lowest annual charges, and that this occurs when the cost of the power wasted in the conductor is equal to the annual interest and depreciation on the conductor investment. The solution of this familiar problem has so often been presented in technical literature that it is unnecessary to review it here. This solution can be greatly simplified so that a very short calculation will suffice. Let the line current be taken at one ampere, and the solution will result in the economic current density in circular mils per ampere. Thus the size for any line current is immediately available. The current used should be figured for the desired power factor. Load factor can be accounted for by using the root mean square value of the ampere load curve. Fig. 1 indicates the economic current density at the intersection of the two curves of annual cost.

The curve showing the annual cost of wasted power is an hyperbola and any number of these may be drawn on the same sheet to cover any desired cost of power per kilowatt-hour. The interest and depreciation curve is a straight line, the position of which depends upon three items,—cost of copper per pound, interest rate, and depreciation rate. The interest and depreciation charge on a pound of copper will then be,

$$K = C\,(i + d)$$

where C = cost of copper cable per pound erected,
i = interest rate,
d = depreciation rate.

A number of lines may be drawn to represent different values of K, and Fig. 2 shows a form of chart which will solve Kelvin's Law for any values of cost of power and copper, and for any rates of interest and depreciation.

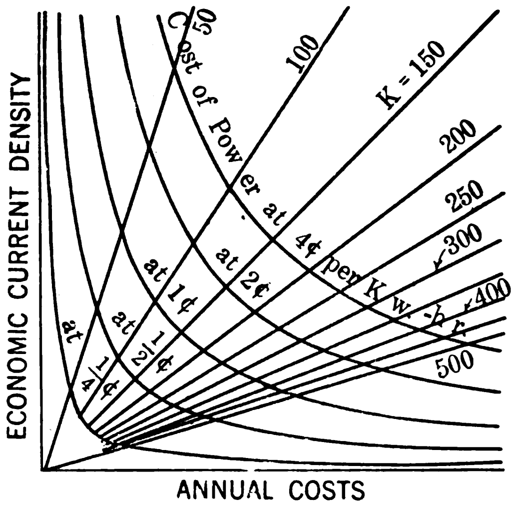

FIG. 2

Fig. 2 may be converted into a more convenient form by plotting cost of power as abcissas, as shown in Fig. 3.

Reference may now be made to the economic current density chart Fig. 5. This is a modification of Fig. 3, in that actual scales are supplied and plotted on logarithmic cross section in order that the curves of Fig. 3 may be plotted as straight lines and also that the scales of the chart may be increased to include any probable values of conductor and power costs.

This chart provides the means for determining the most economical voltage.

The size of copper required to transmit a given amount of power is reduced as the voltage is raised. For best economy the voltage should be raised as high as the corona losses will permit. The critical voltage at which corona begins to appear increases both with the size of conductor and with the spacing, but more rapidly with the former than with the latter. The size of cable, therefore, has the greater effect on the voltage at which corona appears. The effect of altitude is to reduce the voltage at which corona begins to form.

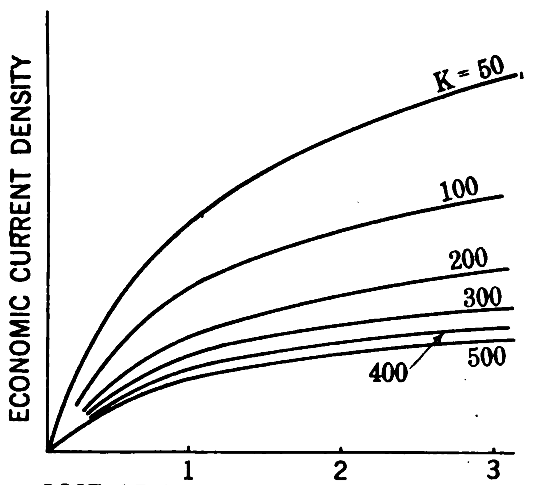

Fig. 3

It would appear then, that Kelvin's Law can be supplemented by a second law covering the line voltage which may be stated thus: The most economical voltage for long transmission lines is the highest voltage possible without excessive corona loss, upon a conductor of Kelvin's economic cross section. The truth of the above statement lies within certain limitations which must be clearly understood. The line must be long enough to prevent the cost of terminal apparatus from controlling the choice of voltage; the cost of switching apparatus and transformers increases very rapidly with the voltage, and for short lines this cost becomes the limiting factor instead of the line economics. It should be noted that the economic voltage for long lines, is a function of the power to be transmitted, and not of the distance of transmission as some rules of thumb have indicated. It is true however, that in some cases the line drop will be excessive when the economic voltage is used, in which case the economic conductor must be departed from, and a larger one used. This will permit the use of a higher voltage, which will further improve the line drop. The line drop could also be controlled by the use of synchronous condensers. Another limitation of this law lies in the fact that even in very long lines, the cost of the supporting structure and line insulators may increase to a point where they outweigh any saving in conductor cost which might be obtained by a further increase of line voltage. A third limitation is that while the line current is decreasing with an increasing voltage, the charging current is increasing and may reach a value much in excess of the load current. Up to a certain point this charging current may be beneficial to the characteristics of the line but it should be remembered that the charging current has a changing value along the length of the line and cannot be completely eliminated by control of power factor.

In spite of these limitations, it is believed that the economic line voltage should be calculated first, as here shown. A cost estimate of the line and terminal apparatus at the nearest standard voltage, and also at the next lower standard voltage, will show whether line conductors or terminal apparatus will dictate the choice of voltage. A conductor of Kelvin's economic section will give the lowest annual charges for a particular voltage; if the voltage is raised, the annual charges and first cost of conductor will both decrease. The most economical voltage for any length of line will therefore be that voltage which gives the lowest estimated first cost when conductors, insulators, supporting structures, terminal apparatus, erection costs, and upkeep are considered.

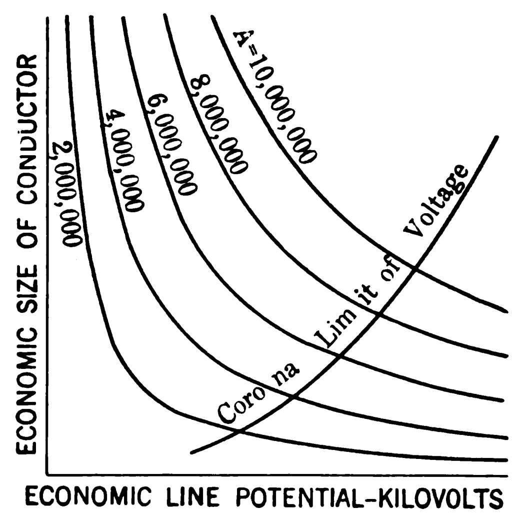

Fig. 4

Kelvin's economic section of conductor for any line voltage may be expressed by the equation,

$$S = D \frac{P}{\sqrt{3}\ E \cos \theta} \text{ for three phase lines where}$$

S = cross section in circular mils,

D = economic current density in circular mils per ampere,

P = root mean square value of power to be transmitted, in kilowatts,

E = kilovolts between conductors at generating end,

Cos θ = power factor of load.

Transposing, this becomes, $E\,S = \dfrac{D\,P}{\sqrt{3}\,\cos\theta} = A$

The second member of this equation is constant for a given set of design constants. This will at once

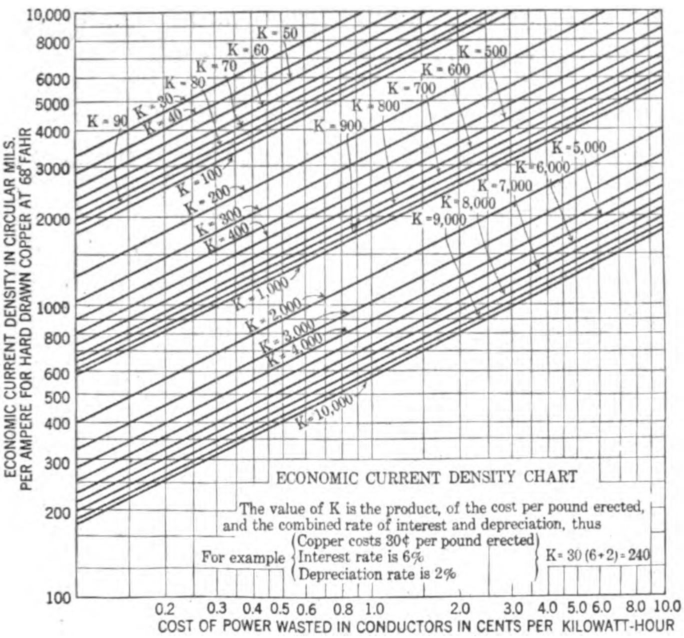

Fig. 5

be recognized as a standard form of the hyperbolic equation with variables in E and S, A being a constant. The whole family of curves can be drawn by suitably changing the value of A. Fig. 4 shows a number of these curves, and also a curve showing the variation of the critical corona voltage with the diameter of line conductor, for a given separation of conductors, and altitude above sea level.

After the value of A has been calculated for a particular problem it is only necessary to follow down the curve corresponding to the value of A as calculated, until it intersects with the corona limit of voltage curve. The asbcissa of this intersection indicates the economic line voltage, and the ordinate the economic cross section. Attention is now called to the economic voltage chart Fig. 6, which is drawn to definite scales as shown, and logarithmic cross section again employed. The corona voltage curves as shown for various altitudes and conductor spacings have been plotted from the tables given in the Standard Handbook for Electrical Engineers, Section 11, and are for stranded cables. It may be remarked that a stranded copper cable has a higher critical corona voltage than solid wire of equal conductivity. The critical corona voltages as shown by the curves are for "weathered" conductor and allowance is made so that the loss during storms will not be excessive. A careful check, using Peek's[1] formula for corona loss, should be made for accuracy under local conditions.

With proper handling these charts may also be used to determine the economic conductor and voltage when either aluminum or steel cored aluminum is employed as a conductor. Specific cost and copper equivalent charts Figs. 7 and 8, have been devised to facilitate the handling of aluminum conductors. By per cent specific cost is meant the ratio of cost of any conductor to a copper conductor, considering equal lengths and conductivities of each, using commercial hard drawn copper as a standard. Actual specific cost is the product of per cent specific cost and current price of hard drawn copper per pound. The copper equivalent chart shows the cross sections of copper and other conductors of equal conductivity. Curves have also been shown on these sheets for magnetic conductors, which could be used in the same way as aluminum were it not for the magnitude of the skin effect. These curves, therefore, may be used for direct current only. Allowance for skin effect has not been made for the copper and aluminum conductors, but since this effect ordinarily will not increase the resistance more than about 2 per cent, it is unnecessary to include this item in the determination of the economic voltage. Tests on steel cored aluminum show that it behaves very nearly as a non-magnetic conductor, and that the aluminum carries practically all of the current.

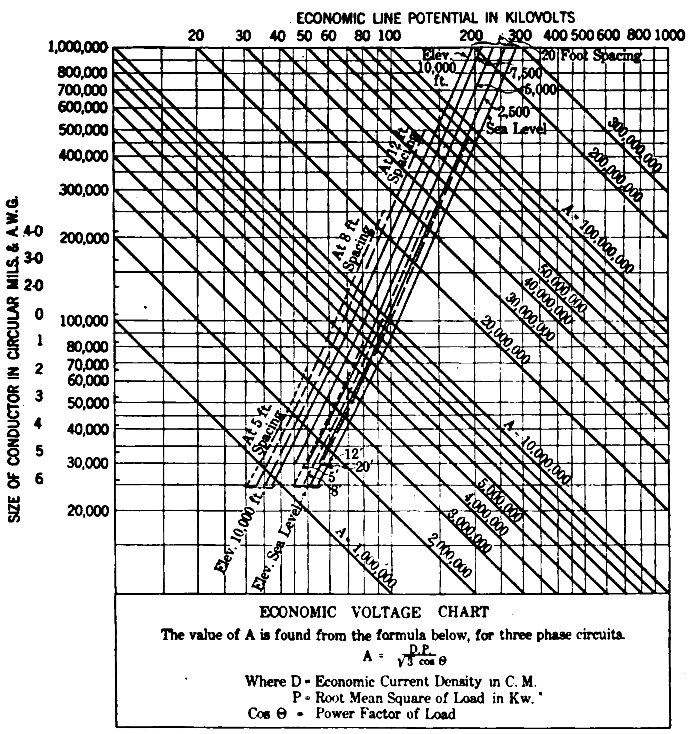

Fig. 6

A concise statement of procedure in the use of the accompanying charts is in order. For a copper conductor, figure the value of K as directed on the economic

1. Trans. A. I. E. E., Vol. 30, p. 1889.

current density chart. Starting with the cost of power at the bottom of the chart, follow the ordinate until it intersects the line corresponding to the value of K, interpolating if necessary. From this intersection follow the abscissa horizontally to the left and read off the economic current density.

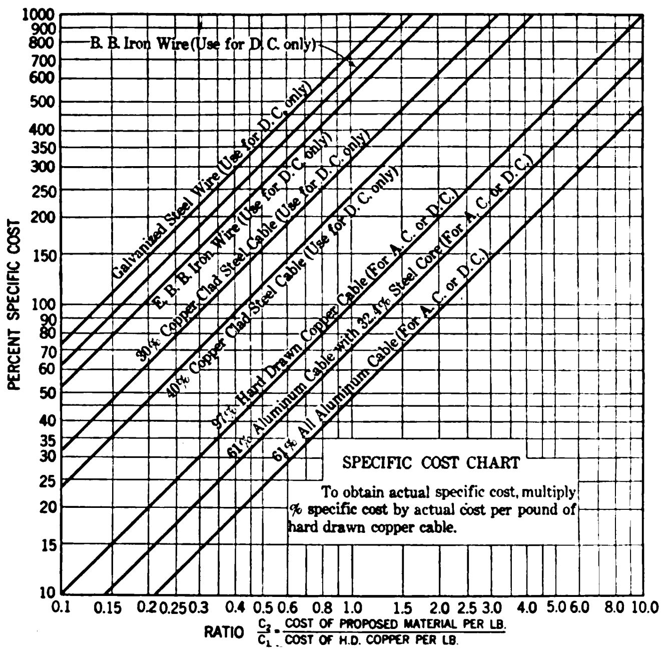

FIG. 7

Turn to the economic voltage chart, and calculate the value of A, using the economic current density found. Place a straight edge on the line corresponding to the value of A just found, interpolating if necessary. Choose now, the curve marked with the elevation of the proposed line. The intersection of this curve with the straight edge is the economic voltage for a 20-foot separation of conductors. If a smaller separation seems advisable, it can be interpolated by the use of dividers and the curves shown for reduced spacing. Having now a pencil point on the straight edge at the desired elevation and spacing, the economic voltage is read at the bottom scale, and the economic section of conductor at the left.

If an aluminum conductor is desired, turn to the specific cost chart and find the ratio C_2/C_1. Follow the ordinate corresponding to the decimal of the ratio until it intersects the diagonal line marked with the desired conductor and follow to the scale at the left and read off the per cent specific cost. The per cent specific cost multiplied by the actual cost of copper gives the actual specific cost. Turn now to the economic current density chart and use as before except that the cost of conductor will be the actual specific cost just found. The economic current density found from this chart is a current density for copper, equivalent in price to the aluminum. Turn to the copper equivalent chart and start on the left hand scale at the current density just found. Proceed horizontally to the line marked "Aluminum Cable" and proceed downward and read off the equivalent density in aluminum. If a steel core is contemplated for this cable, add to this density the *proportionate* circular mils of steel to be used and use this value of current density in the formula on the economic voltage chart. From this point on, use the same procedure as for copper cable.

From the foregoing study we may conclude that the voltage of long trunk lines may be determined by the method shown with small chance that the cost of terminal apparatus will affect the results. Transmission lines serving a number of substations cannot be handled in the same way for the reason that this method indicates different economic voltages for lines of different capacities. For such lines the voltage may be determined for the portion of line carrying the lightest load, and larger conductors used on other portions. As an alternative, the conductors may be made of uniform diameter in all parts of the system, the heavily loaded sections being served by copper conductors, the medium loads by aluminum, and the lightest loads in some cases by iron conductors. A combination of the two plans may be desirable under certain conditions. With the present tendency toward operating voltages of 220 kilovolts and over, the diameter of the cable becomes of great importance, overshadowing high conductivity. The use of iron may thus be given more consideration for these higher voltages, for branch lines especially.

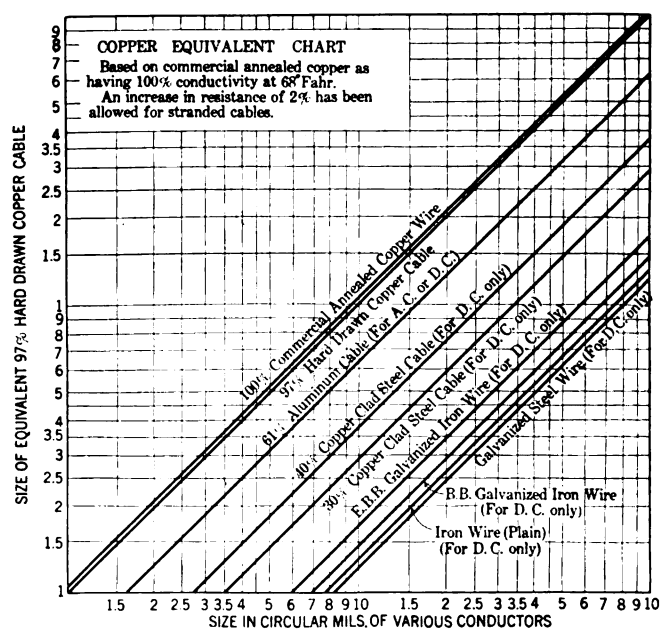

FIG. 8

A cost comparison of various conductor materials can readily be made by applying the method to the conductors in question. The first cost of conductor thus determined will be an indication of its relative value for the proposed line. Of two cables having

the same specific cost with different diameters, the one having the larger diameter will be more economical, from this standpoint, on account of its ability to carry a higher voltage with consequently lower line loss. A selection of conductor material should not be made, however, without a full consideration of its operating characteristics and special construction methods required.

A conductor is not being worked at its maximum economy unless the line voltage is reasonably close to the critical corona voltage. This is in accord with latest principles of line design, and high potential surges are more readily dissipated when the line voltage is just below the critical corona voltage. There is a definite, standard voltage, as well as a definite size and material of conductor to be employed for maximum economy in line design, and all of these points can be readily determined by this method of attack.

Submarine Detection in an Alternating Magnetic Field

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AND
L. O. GRONDAHL
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(*Continued from page 234*)

APPENDIX A

The Amplifier

It has been mentioned that when using a detecting instrument of quite high sensitivity it is necessary to go to very large sizes of the magnet and detecting coil, in order to reach even moderate distances of detection, if no other means are used for increasing the sensitivity.

In all of the subsequent experiments amplifying tubes were used for increasing the sensitivity. The general principle of the operation of these tubes is now well known. The tube has a hot cathode, consisting of a filament excited by continuous current, a plate anode and an intermediate electrode, known as the grid. A continuous voltage is applied between the cathode and anode, resistance being connected in series. The hot cathode emits electrons, thus permitting a constant flow of current between anode and cathode. The amount of electronic emission of the cathode is extremely sensitive to slight variations in the potential gradient in its neighborhood. When used as an amplifier these potential variations are brought in by means of the grid. The resulting changes in the current passing through the tube cause corresponding changes in the voltage drop over the resistance in series with the plate, and consequently very small variations in the potential of the grid are transformed into much larger variations in the potential across the resistance.

The amplifier that was used for the greater part of the detection experiments was constructed specially for this work and had five stages of amplification, the successive stages being coupled by means of resistance.

The voltage amplification, as measured by the manufacturer, with an output resistance of 530 ohms and always using the low impedance stage for the output was as follows:

3 stages	110 times
4 "	1,300 "
5 "	18,000 "

In the experiments on land an input transformer was also often used with the amplifier. In voltage amplification this transformer was somewhat better than one additional stage and used with the transformer, the amplification as given by the manufacturers was:

3 stages	2,600 times
4 "	93,000 "
5 "	1,270,000 "

The impedance of the primary of the input transformer at 30 cycles was in the neighborhood of 70 ohms.

The input transformer was placed in a triple nest of wrought iron boxes, each 3/16 in. thick. Nevertheless, the transformer picked up enough inductive disturbance from the 30-cycle and other circuits to give serious trouble. On land this inductive electromotive force was reduced as much as possible by orienting the transformer until it had a small value. Any small residual from the 30-cycle circuit could be balanced out. The presence of this disturbance, however, often gave serious difficulty in determining the proper commutator setting and in adjusting the capacity to be used in the detecting circuit. On board ship, where the limitations of space prevented a proper choice of the location of this transformer, it was finally abandoned. The loss of amplification was made up by an additional[1] stage of the amplifier, the transformer and three stages having been used in the land tests and four stages of amplification without transformer being used on board ship.

Precautions in use of Amplifier. Having in mind the figures of amplification given above, it will be readily seen how necessary it is to eliminate all types of disturbance in the detecting and amplifier circuits. In using four, or even three stages, very minute disturbances

are amplified to magnitudes greater than that of the detection signal due to the submarine.

Perhaps the commonest types of disturbance are those due to (a) poor connections and contacts in battery, amplifier and detecting circuits; (b) poor electrostatic and electromagnetic shielding. The amplifier itself and all leads should, as far as possible, be enclosed in grounded shields; (c) duplication of ground connections. All shields, conduits and cases should be connected to the same ground; (d) mechanical vibration of the amplifier. Very slight motions of the filament with reference to the grid cause variations in the tube impedance with resulting variations in output voltage. Careful spring suspension of the amplifier is therefore advisable.

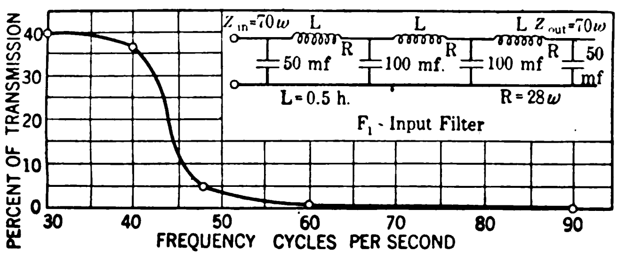

FIG. 6

Any of the foregoing types of disturbance which may be present will appear with no input in the detecting circuit, consequently with care all may be reduced to small values. On land it was found that they could be eliminated to such a degree that four and sometimes five stages could be used, resulting in a quiet galvanometer needle. There are, however, two other types of disturbance which are generally present in practise. They are (1) electromotive forces induced in the detecting circuit by neighboring circuits, (2) harmonic electromotive forces which are not balanced out.

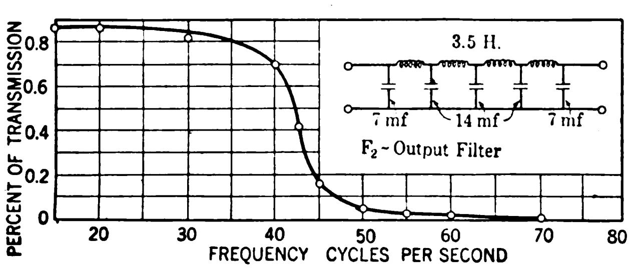

FIG. 7

When the inductive disturbances are of a frequency somewhere near 30 cycles, their presence is indicated by a slow oscillation of the galvanometer needle from one side to the other, the period depending upon the frequency of the disturbance. If the frequency of the disturbance is quite high, it may not cause a deflection of the needle, but result simply in a violent vibration. One disturbance was finally traced through oscillograms to a high commutator bar in a generator supplying some of the circuits of the neighboring building.

When the frequency of the disturbance, whether due to harmonics or to neighboring circuits, is greater than 40 cycles, it can be eliminated by means of "filters" or "pilot conductors" of the general character of those shown in Figs. 6, 7, 8 and 9. Fig. 7 shows a filter for use at the output end of the amplifier; Fig. 6 one designed for 70-ohm terminal conditions, that is, for use between the detecting coils and the primary of the input transformer. The pilot conductors were designed to go between successive stages of the amplifier.

In the experiments on shore the filters were found to be very effective in improving the conditions of balance. They cut out the higher frequencies, in accordance with the curves of Figs. 6 and 7 and do not seriously impair the sensitivity. They do, however, pick up inductive disturbances in the same way as that described for the input transformer. On land it was possible to eliminate these disturbances by proper location and orientation of the filters. On shipboard these preventive measures could not be readily carried out, owing to the limitations of space and the irregular distribution of the various sources of electric and magnetic disturbance. Consequently, in the final experiments on shipboard no filters were used.

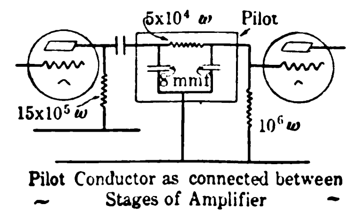

FIG. 8

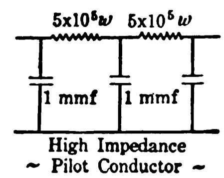

FIG. 9

The pilot conductors greatly improved the conditions of balance in the galvanometer circuit. There was, however, at the same time, a great loss in sensitivity on account of their high impedance. Extensive experiments were carried out with various forms of pilot conductor and invariably with the same result. It is impossible to state whether the improvement of the balance was due to the elimination of troublesome disturbances rather than to the reduction of the sensitivity.

Overloading of Amplifier. It is sometimes possible to balance the system so far as the 30-cycle detection signal is concerned and yet have present high frequency disturbances which do not appear in the balance other than as rapid vibrations of the needle about its zero position, with an amplitude say of three or four scale divisions. Under these circumstances it will sometimes be found that in passing from 3 to 4 stages, there is little or no increase of amplification. The explanation lies in the fact that at three stages the last tube of the amplifier has reached or passed its maximum rated load, the loading being caused by the amplified dis-

turbance. Several methods for studying this condition and its causes were available but cannot be given here.

The best conditions of balance without corresponding loss of sensitivity were always obtained by careful removal of causes of disturbance, identified by various methods. Obscure high frequency disturbances were still further removed by shunting a condenser of 0.0043 microfarads across the input of the amplifier. In this position the condenser is shunted across the high impedance secondary of the input transformer, a combination which constitutes a fairly efficient "low pass" filter.

Under the best conditions on shore, and with careful attention to all sources of disturbance, it was possible to obtain a balance using four stages of amplification and the input transformer, or five stages without the transformer. These balances were so sensitive and susceptible that they were obviously unsuited for work on shipboard. They were therefore not used for taking detection observations for use as a basis in computing results in practise.

Conditions on Shipboard. As anticipated, the conditions on shipboard were radically different from those encountered in the earlier work. Two most serious disturbances were those due to the vibration of the boat, caused by the engines, and the change in relative position of the magnet and the detecting coil, due to the straining of the hull of the ship. The effect of vibrations of the engines was considerably reduced by supporting the amplifier on springs. For these reasons it was found that the extreme value of amplification that could be used was four stages. As already mentioned, the input transformer was found to be unsuited to conditions aboard ship. The shunt to the galvanometer was also usually set much lower than 90 ohms and often as low as 10 ohms.

Under the above conditions, in quiet water and uniform speed, it was usually possible to secure a fair working balance. This balance, however, was invariably upset by sudden changes of speed, by rough water, or by a sharp change of course.

Toward the end of the experiments on board ship another amplifier with electro-magnetic coupling was used. This amplifier was not disturbed by a vibration of the boat to quite the same extent, apparently due to smaller, more compact, construction of the tube electrodes. This improvement was not however sufficiently great to permit an increased degree of amplification with resulting increase in the distance of detection.

APPENDIX B

Regulation for Constant Speed

Extreme constancy of speed is highly essential for maintaining the balance in the detecting circuit under conditions of high sensitivity.

Regulation by Tuning Fork. The method of speed regulation which was used throughout the greater portion of the experiments is indicated in Fig. 10. In this method the ultimate source of constant speed is an electrically operated tuning fork. A small rotary converter of the same frequency as the tuning fork is driven from the direct-current end and is loaded with a resistance on the alternating-current end, the load circuit being taken through a pair of contacts on the tuning fork, contact being made once during each half wave. The time interval of contact on the tuning fork is a fraction of the whole alternating-current period. If the speed rises, contact is made at an instant when there is a greater electromotive force and current, thus resulting in a greater load on the converter. If the speed goes down, the conditions are reversed, consequently the tendency of the change of load is to maintain the speed of the converter constant. This tendency can be made greater or more positive by inserting resistance in the armature circuit of the continuous-current end of the converter.

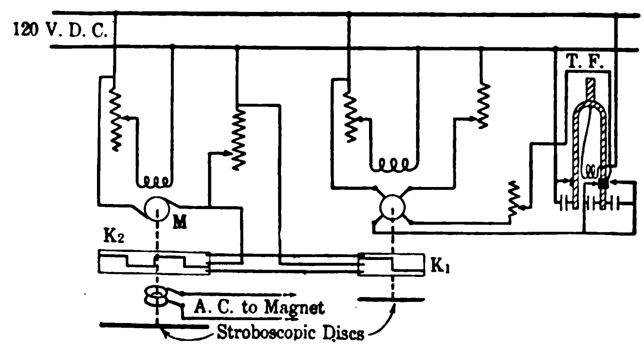

Fig. 10

The shaft of the small converter and that of the larger machine which is to be controlled are each supplied with a crown commutator. The number of commutator segments for each is chosen so that by their speeds the frequencies of reversal of the two commutators are the same. For example, in the experiments on S. C. No. 326, the speed of the generator for exciting the magnet was one half that of the regulating converter, consequently the numbers of commutator segments in the respective cases were four and two. The commutators were connected together, as indicated in Fig. 10, in such a way as to short-circuit a small resistance in the armature circuit of the main driving motor for a greater or less period, according as the commutators depart more or less from the position of exact coincidence of phase. The machines automatically find such a relative commutator phase relation than an increase in speed decreases the duration of short circuit of the armature resistance, and vice versa, so that the average voltage on the motor armature is such as to more or less exactly maintain the speed in a constant relation to that in the small converter, which in its turn is maintained constant by the tuning fork. The introduction of the small converter is necessary, since the tuning fork contacts will not carry the large

currents interrupted in the control of the considerably larger direct-current motor. The plan, as outlined, was used to control the speed of a 90 h.p., 230-volt, continuous-current motor operating at about 40 h.p. The speed of this machine was maintained constant by this method to within approximately. 0.5 per cent.

A number of modifications of the above method were tried, but without equal success. Among them were the following:

1. Apply a load to a small auxiliary alternating-current generator, mounted on the shaft whose speed

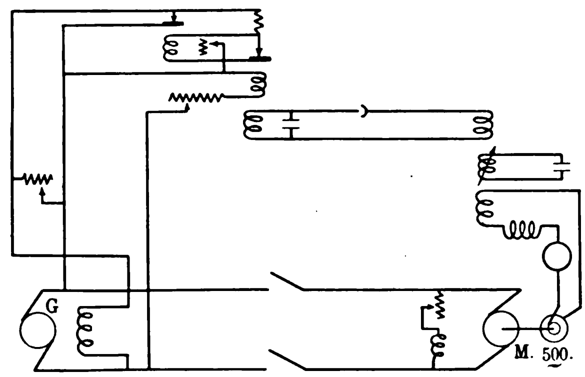

Fig. 11—Alexanderson Speed Control

is to be controlled, interrupt the load of the alternator by the commutators, thus regulating the speed in a manner similar to that in the combination of the small converter and tuning fork. The load necessary was found to be too great and the voltage between commutator segments too high, resulting in serious sparking.

2. The commutators were used to short-circuit a resistance in the field circuit of the main driving motor, rather than in its armature circuit. It was thought that the smaller value of current involved would result in an improvement in commutator action. However, the magnetic inertia of the field and the consequent slow action resulted in pronounced hunting of the larger machine.

Alexanderson Method of Speed Regulation. On shipboard motion of the ship caused the armature of the small converter, described in the foregoing method, and also that of the main motor generator to shift in their bearings, resulting in variable friction, and consequently in irregular variations of speed. Ball thrust bearings improved conditions somewhat, but not completely. The following method, due to Mr. E. F. W. Alexanderson, of the General Electric Co., was, through the courtesy of Mr. Alexanderson, studied as adapted to our needs, and finally put into operation.

The method is indicated by the diagram of Fig. 11. The essential features are a combination of an ordinary continuous-voltage regulator with a resonant alternating-current circuit. The resonant circuit is excited by a 500-cycle generator, geared to the shaft of the machine whose speed is to be controlled. The natural frequency of the tuning circuit is adjusted by variable reactance and capacity, so that the desired speed of the main generator is on the steep portion of the rising limb of the resonance curve. This circuit is loosely coupled to a circuit containing a vacuum tube rectifier and a part of one of the coils of the voltage regulator. When the speed rises for any reason, the current in the resonant circuit increases and thus operates the voltage regulator just as though there had been a rise in voltage. The regulator is therefore affected by either a rise in voltage or a change in speed, or both operating simultaneously. The 500-cycle generator was taken from an Army radio "pack set" and weighed only 40 lb.

This method of speed control is very positive in action. The closeness of its control was tested by comparison with a tuning fork. By a system of mirrors the amplitude of the tuning-fork vibration was greatly extended and a stroboscopic disk on the generator shaft permitted a close estimate of the momentary fluctuations of speed of the main generator shaft. These momentary variations were found not to exceed 0.04 per cent.

Temperature, or other slow variations of conditions, will cause a slow change in speed with the Alexanderson apparatus. Such slow changes, however, are of relatively small importance in their bearing on the balance of the detecting circuit. Sudden changes of small duration are the most troublesome. The use of the Alexanderson method therefore greatly improved the conditions of balance.

The tuning-fork method is free from the slow changes due to temperature, and it appears that a further refinement in speed control might be possible by using both the tuning-fork control and the Alexanderson control on the same shaft.

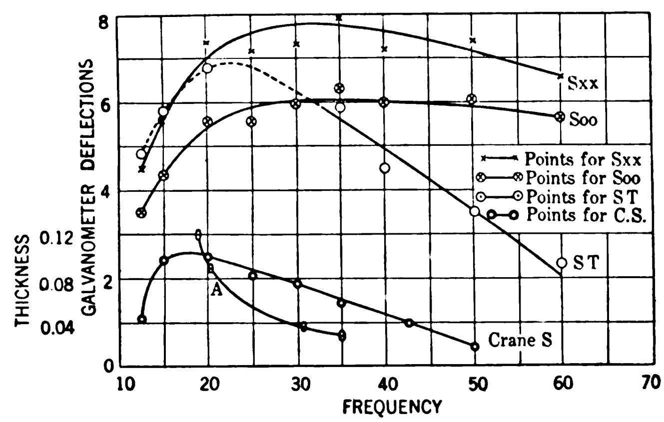

Fig. 12—Effect of Frequency on Sensitivity

APPENDIX C

Choice of Frequency

Early in the work at Baltimore a study was made, with a number of experimental submarine models, on the sensitivity of detection as affected by the alternating frequency. Some of the results are shown in Fig. 12.

The curves indicate that for every thickness tried

there is a frequency at which the deflection of the detecting instrument for a given distance of the submarine is a maximum. These curves were all taken with approximately constant flux in the magnet.

With a given strength of field at the submarine, due to its magnetization the electromotive force in the detecting coil rises with the frequency. The influence of secondary currents and eddy currents set up in the hull, however, also increases with the frequency, thus resulting in an increasing demagnetizing effect. The resultant maximum may therefore be due to the preponderance of the former effect at the low frequency, and of the latter effect at the high frequency.

With increasing thickness of the submarine, and indicated by the curves, the maximum of detection signal tends toward lower frequencies. (See curve *a*, Fig. 12, showing relation of thickness and maximum deflection). For the thickest submarine the maximum is also more sharply marked.

The earlier experiments with submarine models of the smaller thicknesses had indicated 30 cycles as the region of maximum sensitivity. The latter experiments, above described, rather indicate that a still lower frequency might be better suited for service in actual practise in which the thickness is greater. However, the relative distances and strengths of field at submarine and coil were different in several instances, thus introducing factors which are necessarily uncertain and which might therefore upset this conclusion. In any event, as indicated by the curves, there is relatively small gain in sensitivity in going from 30 cycles to say 15 cycles. As machines and other equipment adapted to 30 cycles were readily available, and those of lower frequency not obtainable within a reasonable time, the experiments were continued at 30 cycles.

APPENDIX D

Tests of Formula 11

The relations shown in Formula (**11**) were tested in the laboratory in an extensive series of experiments. Model submarines of different lengths, diameters, thicknesses and material were tried under as nearly as possible the same conditions. In addition, the inverse sixth power of Formula (**10**) was tested. No attempt will be made to include a complete account of these experiments here. The general results only will be given.

Formulas (**10**) and (**11**), for computing the distance of detection, show that if D is small compared with d, the signal should be inversely proportional to the sixth power of d. When D has a value that is more nearly comparable with the value of d, the increase of the signal with the decrease of d is proportional to some higher power of d.

The conclusion of the foregoing paragraph was readily tested by reading the variation of the signal in the detecting instrument with the approach of the submarine. With D equal to 5 ft. 8 in. and d decreasing from 15 ft., the signals were found to vary with approximately the inverse eighth power of d over the relatively short distance in which the comparison could be made. When D was reduced to 2 ft. or less, the average of a number of runs showed that the signal varied inversely as d to the power 6.2. A number of similar tests, all made with arrangement A of Fig. 1, indicated that the inverse sixth power was approached the smaller the value of D.

The tests as to the variation of the dimensions of the model were made with three models of the same size as S, but of different thicknesses, namely, 0.025 in., 0.0375 in. and 0.0625 in., and also with two models of different diameters, as well as different thicknesses. All were separable into several sections. (See Tables 1, 2 and 3).

The influence of the length of the model on the signal is given in Table I. The average ratio of the lengths in

TABLE I
INFLUENCE OF LENGTH OF SUBMARINE

Length	Signal		Length	Signal		Diam.	Thickness	Ratio of Lengths	Ratio of signals	
	$d=15'$	$d=12'$		$d=15'$	$d=12'$				$d=15'$	$d=12'$
96 "	3.35	17.5	70 "	2.82	15.4	1′	0.0625″	1.37	1.19	1.14
96 "	3.35	17.5	35½ "	1.08	8.03	1′	0.0625	2.71	3.10	2.18
70 "	2.82	15.4	35½ "	1.08	8.03	1′	0.0625	1.97	2.61	1.92
96 "	1.75	8.2	69½ "	1.35	7.6	1′	0.025	1.38	1.30	1.08
69½ "	1.35	7.6	36 "	0.80	4.1	1′	0.025	1.93	1.69	1.85
96 "	1.75	8.2	36 "	0.80	4.1	1′	0.025	2.67	2.19	2.00
84 "	3.97	23.0	55 "	2.70	18.5	2′	0.0625	1.56	1.47	1.24
55 "	2.70	18.5	30 "	1.85	12.4	2′	0.0625	1.83	1.46	1.49
84 "	3.97	23.0	30 "	1.85	12.4	2′	0.0625	2.80	2.15	1.86
56 "	2.35	15.3	28 "	1.80	10.7	2′	0.025	2.02	1.31	1.43
84 "	3.65	18.9	56 "	2.35	15.3	2′	0.025	1.50	1.51	1.24
84 "	3.65	18.9	28 "	1.80	10.7	2′	0.025	2.03	2.03	1.77
16 ft.	3.90	..	10 ft.	3.43	..	1′	0.025	1.6	1.14	..

the comparisons which are recorded is 2.06. The corresponding average of the ratio of the signals is 1.72. The curve of Fig. 13 shows clearly that when the length of the submarine is comparable with d, its effective length as a magnet decreases rapidly with the distance from the main magnet. It is therefore to be expected that this ratio, as observed on sections of varying length, should be lower than the ratio of the actual lengths. The last line in the table gives an exaggerated case of difference in the comparison of a 10-ft. submarine with a 16-ft. submarine. The ratio of signals is 1.14. This instance has not been included in taking the average mentioned above.

The influence of the diameter of the model is shown by the results of Table II. The average of a number of tests indicated that the signal increases directly as the diameter, the ratio of the diameters being 2 and the average ratio of the signals being 1.91.

The results of a study of the influence of the thickness of the wall of the model, shown in Table III, are not so definite. The ratio of thicknesses of wall is in two

cases 2.5. For the submarine of 1-ft. diameter the average ratio of signals was 1.92, but for models 2 ft. in diameter the ratio was only 1.13. A possible explanation may lie in the greater demagnetizing influence in circulating and eddy currents in the case of the model having larger diameter and greater thickness. The conclusion here is obviously not definite, but indicates at least some increase of signal of detection with increasing thickness of the shell of the submarine. It should be borne in mind, in all tests, of this character that there is a great element of uncertainty as to the continuity of the magnetic structure of an actual submarine. It seems quite possible that the caulking and painting of the plates may well interpose non-magnetic layers which would seriously offset the simple relations

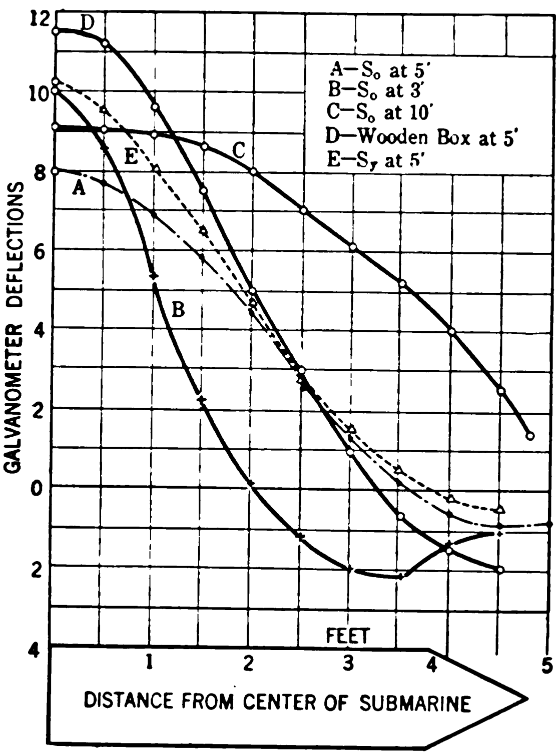

Fig. 13—Magnetization of Submarine

which are assumed in Formula (**11**). It was clearly recognized, through all the work of this character, that the experimental conditions probably differed markedly from those which would actually obtain in the case of the application to full size submarine. On the other hand, it appeared a matter of considerable importance that the approximate relations of the formulas should be tested.

By the method of derivation of Formula (**11**), it is shown that the distance of detection, using arrangement *B* of Fig. 1, should be greater than that of arrangement *A* by a factor the sixth root of 4, that is, 1.26. Owing to the limited distance of detection in the laboratory experiments, there are few possibilities for a convenient and certain test of this relation. From a number of tests in this direction only one will be given here:

Arrangement *A*. Distance for a standard signal—11.25 ft.

Arrangement *B*. Distance for the same signal—15 ft.

The ratio of these two distances is 1.33, indicating that the actual sensitivity of arrangement *B*, as compared with arrangement *A*, is greater than indicated by theory.

There appeared to be no reason why tests, of this character should be extended further to a more careful

TABLE II
INFLUENCE OF DIAMETER
Ratio of Diameters = 2.

Signal			Ratio of signals		
$d = 15'$	$d = 12'$	$d = 15'$	$d = 12'$	$d = 15'$	$d = 12'$
3.82	18.6	1.73	7.85	2.21	2.37
3.35	17.5	4.20	22.3	1.26	1.28
2.82	15.4	2.70	18.5	1.22	1.53
1.08	8.03	1.85	12.4	2.03	1.83
3.35	17.5	3.97	23.0	1.36	1.50
1.80	10.7	0.80	4.1	2.92	3.39
2.35	15.3	1.35	7.6	2.16	2.50
3.65	18.9	1.75	8.2	2.38	2.64
3.35	17.5	3.97	23.0	1.36	1.50
2.82	15.4	2.70	18.5	1.24	1.53
1.08	8.03	1.85	12.4	2.03	1.83

determination. The object of all of this work was to check, to only an approximate degree, the relations of Formula (**11**), so that they might be used as a basis for the design of larger equipment.

APPENDIX E

Electric Balance in the Detecting Circuit

A question which arose early in the laboratory tests was the proper setting of the commutator for the maximum signal in the detecting coil due to the magnetized submarine. This question was answered experimentally by taking a number of detection observations with different commutator settings. A balance was obtained for each setting by rotating the balance coil *C'*, the detecting coil remaining fixed, and then bringing up the model submarine to a definite standard position.

TABLE III
INFLUENCE OF THICKNESS
Ratio of Thicknesses = 2.5

Diameter	Signal				Ratio of signals	
	0.0625		0.025			
	$d = 15'$	$d = 12'$	$d = 15'$	$d = 12'$	$d = 15'$	$d = 12'$
1'	3.35	17.5	1.75	8.2	1.91	2.14
1'	2.82	15.4	1.35	7.6	2.09	2.03
1'	1.08	8.03	0.80	4.1	1.37	1.99
2'	3.82	18.6	4.2	22.3	1.10	1.20
2'	1.80	10.7	1.85	12.4	0.95	1.07
2'	2.35	15.3	2.7	18.5	1.17	1.23
2'	3.65	18.9	3.97	23.0	1.09	1.22

The conclusion from these experiments was that the phase of the signal from the submarine is practically co-incident with that from the main magnetic field due to the magnet, and that therefore the proper commutator setting for the submarine signal was the same as that pertaining to the electromotive force induced in the detecting coil by the magnetic field of the magnet. This conclusion was subsequently checked in the experiments afloat by making detection observations for different commutator settings. The simplest steps for obtaining a balance then are: to set the detecting coil with its plane approximately normal to the magnetic field, to cut out the balancing coil or rotate it until its plane is approximately parallel to the field, to insert a high non-inductive resistance in the detecting circuit in order to limit the current in the detecting instrument, inductance being already balanced with capacity, and then to rotate the brushes around the commutator to a point where the galvanometer deflection is zero. At this setting the current in the detecting circuit is chopped up into equal positive and negative quarter-waves. The commutator is then rotated 90 electrical degrees, in which position it will indicate, to a maximum degree, all disturbances in the detecting circuit which are in phase with the electromotive force induced in the detecting coil by the main field. The non-inductive resistance is now cut out, the balancing coil inserted and rotated to give a balance, as indicated by the detecting instrument.

In the early experiments, before the amplifier was used, it was found possible to obtain a very satisfactory balance with the above method, using a D'Arsonval suspension galvanometer of 83-megohms sensitivity, and the experiments of the type recorded on page 228 were taken under these conditions, but even at this time it was obvious that there were disturbances in the detecting system which could not be eliminated by the simple operations of commutator setting and rotating the balancing coil. At this point there began a study of the conditions of balance in the detecting circuit which extended through the entire period of the work, both ashore and afloat. With increasing sensitivity in the detecting circuit, there always appeared new types of disturbance which had to be attacked and, as far as possible, eliminated. In fact, the one problem in increasing the distance of detection is to increase the sensitivity of the detecting circuit, as shown in Fig. 2, without at the same time permitting the entrance of many types of common disturbance which are normally of greater magnitude than the signal due to the submarine.

Along with the various steps in the increase of the sensitivity, there was a continuous process of refinement of electric and magnetic screening and the rigid fastening of all leads and coil supports in the detecting circuit. It was found that this circuit must be grounded at one single point. If there are two grounds connected by a single stretch of wire in this circuit, under conditions of high sensitivity enough difference of potential arises to mask the signal.

Disturbance of the position of the galvanometer needle about its zero naturally led to studies of the commutator and of changes in voltage and frequency in their influence on the magnet excitation. The development of the commutator finally led to a rigid mounting on the end of the generator shaft, careful machine construction with narrow mica insulation between segments, and to quite narrow brushes with light spring tension. These brushes were usually made of three layers of brush copper with a thin steel backing for the spring tension. The commutator was kept clean by a rather sparing application, once or twice a day, of high-grade lubricating oil, with a clean rag.

Variations of both frequency and of voltage were found at once to upset the balance very violently. It became evident that the greater portion of the disturbances were due to these causes, especially to frequency variation. Efforts were directed not only to obtain constancy in these particulars, but also to a study of the possibility of compensating in some way the disturbances themselves. Since constancy of frequency is only a relative term, it is obvious that with increasing sensitivity possible disturbances, due to frequency variations, will continually appear.

If the system without amplifier is balanced, as described above, and the commutator be then rotated to successive positions, it will be found that the balance is upset, showing the presence of a residual disturbance in the detecting circuit after it is balanced. The wave form of this disturbance may be taken and while it is distorted in shape, its principal component is that of the fundamental 30-cycle frequency, thus showing the presence of an electromotive force which is displaced 90 degrees from that induced by the main field. This led to the question of a difference in phase in the electromotive forces in the detecting and balancing coils, and an experimental study promptly revealed the fact that with increasing distance from the magnet there was a continual lag in phase of the main magnetic field. It was subsequently found that this condition obtained with all three of the magnets. In the case of the laboratory magnet, M_1, for example, there was a lag of 4.5 electrical degrees in moving the detecting coil from a distance 4 ft. to a distance 17 ft. from the magnet. This residual may be balanced out in a number of ways, as described below, and in this way it was found that the disturbance due to frequency variation is very greatly reduced, and that due to voltage variation practically disappears when this residual is completely balanced out.

Two of the earliest efforts to balance out the residual electromotive force, due to the difference in phase in the electromotive forces in the detecting and balancing coil, should be described. In the first of these, the electromotive force in the detecting coil was balanced by a few turns taken completely around the main

magnet, the process of balancing being accomplished by rotating the detecting coil. It was found that by moving the balancing coil to different positions on the magnet, a place could be found for which a given change in frequency or voltage could be compensated; *i. e.*, on making this change there would be no upset of the zero reading of the detecting instrument. The second method involved moving a balancing coil to different positions in the neighborhood of the magnet in an effort to find a position in which the phase of the electromotive force in this coil was co-incident with that in the detecting coil. Sometimes this position could be found with resulting great improvement in the balance. Neither of these arrangements was satisfactory, the first because it compensated only for frequency

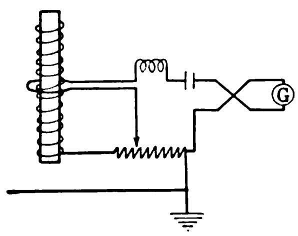

Fig. 14

and voltage changes of definite magnitude, and the second because the position described could not always be found.

The introduction of the amplifier greatly accentuated the influence of the residual electromotive force in the detecting circuit. Its presence became immediately evident in the balanced condition by a 60-cycle vibration of the galvanometer needle. The amplitude of this vibration would be normally two or three divisions of scale and thus became a ready means of determining the presence of a residual electromotive force. The vibration, or "wiggle," of the needle is obviously caused by the chopping up of the 30-cycle residual at its maximum point, since the commutator is set for a disturbance differing in phase from it by 90 electrical degrees.

Methods of Eliminating Residual Electromotive Force. Following is a list of some of the methods which were tried for eliminating the residual electromotive force in the detecting circuit.

1. Shunt the balancing coil with a non-inductive resistance, so that the electromotive force in the terminals of this resistance is in phase with the electromotive force in the detecting coil. See Fig. 2. This was the method finally adopted. The coil is rotated for balancing.

2. Introduce into the detecting circuit an electromotive force derived from the circuit exciting the magnet:

a. By resistance in series with the magnet winding, Fig. 14.

b. Inductively from a coil in series with the magnet winding and acting on the balancing coil.

c. Inductively from a coil excited by connection across a resistance in series with the magnet winding and acting on the balancing coil.

d. Inductively from a coil in parallel with the magnet winding.

e. Inductively from a coil excited from the terminals of the balancing coil.

3. Insertion of an electromotive force exactly equal and opposite to the residual electromotive force from a Drysdale alternating-current potentiometer arranged as a variometer:

a. Excited by split phase from the main generator.

b. Excited from a small two-phase generator mounted on the shaft of the main generator.

4. Omit the balancing coil and insert in the detecting circuit an electromotive force from the variometer exactly equal and opposite to the electromotive force in the detecting coil due to the main magnet field.

The residual electromotive force may be neutralized by any one of the methods mentioned above, by the following experimental adjustments:

1. Set the commutator for maximum current due to electromotive force in the detecting coil.

2. Balance C and C' by varying position or angle of C.

3. Shift commutator 90 electrical degrees, that is, for maximum current due to residual electromotive force.

4. Balance out the residual by resistance drop over resistance in series with magnet winding, or by any of the other methods described in the foregoing paragraph.

5. Shift commutator back 90 degrees.

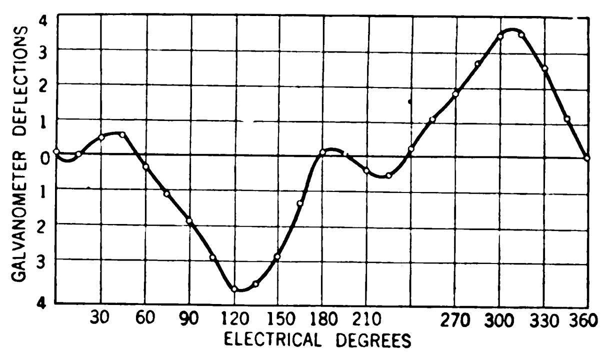

Fig. 15

6. A greatly improved balance will result, but if not yet perfect, the above process is repeated.

By the above methods the conditions of the balance were greatly improved, but they were still found to be very sensitive to changes in frequency. Although the residual was found to be balanced out, there was always to be found, by rotating the commutator or by taking an oscillogram, a highly distorted wave of current in the detecting circuit. The presence of this wave can be detected simply by rotating the brushes about the commutator, taking readings at different positions. Fig. 15 shows a curve taken in this way, after the sys-

tem is balanced and the 30-cycle residual removed, as far as possible, by one of the methods mentioned above. Obviously the curve of Fig. 15 does not show the true wave form, but serves only to indicate the presence of a disturbance made up of higher harmonic frequencies.

None of the foregoing methods of eliminating the residual electromotive force eliminated the disturbance due to frequency variation and several of them made this type of disturbance even worse.

Disturbances Due to Changes of Frequency. As has been already stated, the electromotive forces in the coils C and C' differ in phase. A number of causes for this may exist but the most obvious appears to lie in the difference in phase between the magnetic or stray field of the magnet winding alone, and that due to the main flux in the core of the magnet. These two fields differ in phase and combine in varying relative magnitudes at different points. This appears to be borne out by the fact that there is an increasing lag in phase with increasing distance from each of the magnets, M_1, M_2 and M_3. However, it will also be recalled that in close proximity to other magnetic and conducting masses there is also a shift in the phase of the magnetic field, undoubtedly due to magnetic and electric reactions of these masses. Whatever be the nature of the explanation of the shift in phase of the main magnetic field, it is obvious that the phase pertaining to any particular point will be different for different values of frequency.

The fields in the detecting and balancing coils are not unidirectional, but are rotating. This was readily determined experimentally in attempting to rotate a detecting coil so that its plane should be parallel to the field, and thus have in it no electromotive force. No such position could be found, and by the means mentioned it was readily possible to measure the relative magnitude to the two components of the rotating elliptical field at any point. For example, the magnitude of the right angle component in one position of M_1 was found to vary with the position of C between 1 per cent and 2 per cent of the principal component. With a change of frequency the relative magnitudes of these two components will also change.

In view of the foregoing, it would appear that the following are the principal causes which may lead to an upset of the electrical balance in the detecting circuit when a slight change of frequency occurs.

1. Inequality of phase between C and C'. Referring to the vector diagram in Fig. 16, if there exists a residual electromotive force R due to a difference in phase between C and C', a change of frequency will shift the position of the parallelogram and bring a component of R into the setting of the commutator. With a residual present equal to 50 divisions on the galvanometer a change of phase of 11 deg. would produce a deflection of 10 divisions.

2. If C and C' are in exact opposition in phase, a change in frequency will, in general, result in a shifting of the phases of C and C' in different amounts. This will cause a resultant electromotive force between them, a greater or less component of which will appear in the setting of the commutator. A simple calculation shows that in the case of M_3 and C_3 in the relative positions used on board ship, a phase difference 0.025 seconds would cause a deflection of 10 divisions on the galvanometer.

3. If C' is shunted so as to bring the electromotive force at its terminals into exact opposition with the electromotive force in C at one frequency, a change in this frequency will result in a change in both magnitude and phase of the electromotive force at the terminals of C'.

4. Since the magnetic fields at both C and C' are rotating, a change of frequency will change the relative values of the principal and right-angle components of these fields and, in general, by different amounts in the two coils, and so will result in an upsetting of the balance.

5. Under the best conditions of balance obtained, it has always been found that there is a residual current in the detecting circuit having a complicated wave form. This harmonic residual in the balanced condition is chopped up by the commutator for normal frequency. A change in the fundamental frequency will be multiplied correspondingly for higher harmonics which would naturally result in a displacement of the harmonic residual, so that it is no longer chopped up by the commutator, thus resulting in a zero upset.

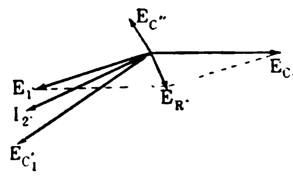

FIG. 16

Compensating of Frequency Disturbance. Since disturbances due to frequency variation may be used by any one of the methods mentioned in the foregoing paragraph, it is obvious that it should be possible, by the introduction of one or more of these causes, to compensate the existing disturbance in a particular location and arrangement of the whole detecting equipment. For example, out of a great number of combinations which were tried, the two following may be mentioned:

(a) Balancing C against a derived circuit on C', the characteristics of this latter circuit being so adjusted that the zero upset resulting from a small frequency change was as nearly as possible a minimum. This adjustment could be made by a cut and try method, using a definite frequency change in successive trials.

(b) With C and C' balanced as in the simple circuit of Fig. 18 to balance out their resultant with a derived electromotive force, the characteristics of

which were chosen so that the zero upset for a given small change of frequency was as nearly as possible zero.

An illustration of the type of circuit used for class (a) may be seen in Fig. 17, where C is balanced against an electromotive force across C and R. Fig. 18 shows a combination of the two, in which E_c is balanced against the resultant of E' and E_c''. Here it is possible to vary the effect of frequency on both the electromotive forces used to balance the electromotive force of C. E_1 is, in general, not in exact opposition of phase with E_c. The resultant of E_1 and E_c'' however may be brought into exact opposition.

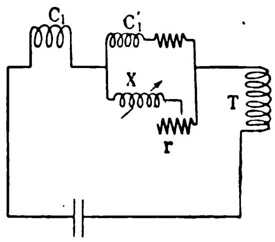

FIG. 17

These methods of eliminating a given frequency disturbance had two serious drawbacks:

(a) The amount of manipulation necessary to obtain the balance and

(b) The resultant balance, although independent of a frequency change of a given magnitude, still had a large zero disturbance in the final balanced position. The exact cause of this disturbance could not be found, but it is assumed that compensation for a frequency change of one amount is not necessarily effective for a frequency change of a different amount.

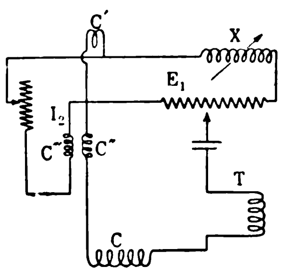

FIG. 18

Too conspicuous conclusions resulted from the work indicated in the foregoing; the first, the more complete the coincidence of phase in electromotive forces in C and C', the less the disturbance of the balance conditions by change in speed of the generator; and second, it is always possible to overtake an improvement in speed control by such increase in sensitivity as will still leave speed variations as a limiting factor to sensitivity of the detecting circuit.

Final Technique for Obtaining Balance. Since it is not possible to compensate all frequency variations, it appeared best to maintain the speed as nearly constant as possible and then adopt the simplest method available for bringing the electromotive forces in C and C' into exact opposition of phase. The two most satisfactory methods for speed control are described in Appendix B.

As already stated, the phase of the field due to the magnet lags more and more the greater the distance from the magnet. Unless therefore either C or C' is in close proximity to a large magnetic mass, it will be found that the phase of the electromotive force in C' leads that in C, since C', owing to its small size, is always nearer to the magnet. If now C' be shunted by a non-inductive resistance, the value of this resistance may be so chosen that the electromotive force at its terminals is exactly in phase with the electromotive force in C. The magnitude of the electromotive force at the terminals may be varied by rotating C' in the main magnetic field. Since C' and the shunt resistance may both be located within convenient reach on the observer's table, this appears as simple a method as may be found. Following are the successive steps in obtaining a balance by this means:

1. Set commutator for the maximum signal due to the electromotive force in the detecting coil C, by setting for zero deflection.

2. Shift the commutator brushes 90 deg. and balance out the electromotive force due to C by rotating C'.

3. Shift commutator back 90 deg. and balance out the residual by varying the resistance in shunt with C'.

4. Repeat (2) and (3) until the out-of-phase component is out and a good balance results.

Very often the proper value of shunt resistance may be found by noting the magnitude of the vibration, or "wiggle," of the galvanometer needle. A variation of the shunt resistance is reflected in the amplitude of this vibration. This method obviates the necessity of shifting the commutator away from the position (2), but is not as exact as the complete operation as described.

Ordinarily only a few minutes are required to make the complete balance adjustment, and once made a single adjustment is usually sufficient to rebalance after any upset of balance due to slow temperature changes.

Other Disturbances. The stability of the balance may be affected by a number of extraneous causes, and some of those encountered are mentioned below:

(1) Inductive disturbance from circuits and machines even at considerable distances from the detecting circuit. These disturbances could, in some cases, be neutralized inductively by placing a loop of the offending circuit in proper relation to the detecting circuit.

(2) Temperature changes often caused slow creeps of the galvanometer zero. These changes are usually present unless the whole equipment has been warmed up by a sustained period of operation.

(3) The harmonic residual always present in the

best balances appeared at maximum sensitivity as a vibration or shake of the galvanometer needle, quite different in appearance from the "wiggle" mentioned above. These disturbances may be eliminated by means of filters, or pilot conductors. (See Appendix A).

(4) Mechanical vibration of the amplifier. On shipboard this was completely obviated by spring suspension of the amplifier.

The many refinements of adjustment and elimination of disturbances, suggested in the foregoing paragraphs, were studied and used principally in the tests on shore. On shipboard the conditions, as regards mechanical vibration due to the engines and motion in the sea, became the limiting factor when the sensitivity was increased. Although, as stated, S. C. No. 326 was an unusually steady boat, it was nevertheless found that the changes in the relative position of the magnet, detecting and balancing coils, was the limiting factor; consequently, it was not possible to use the extremes of amplification and sensitivity that have been used on shore. Nevertheless, the care which had been given to the elimination of disturbances had resulted in such an improvement in the general makeup of the equipment that it was possible to use between three and four stages of amplification in increasing the sensitivity. This was approximately one stage less than used in the best shore tests, and consequently many of the refinements necessary in the latter tests for eliminating disturbances were not necessary on shipboard.

Other Forms of Balance. The foregoing discussion refers particularly to the arrangements *A* and *B* of Fig. 1. A number of other arrangements of the detecting coil were tried, but without noticeable advantage. One of these should be mentioned. The detecting coil is arranged with its plane parallel to the direction of the field of the main magnet. This arrangement is not practicable, by reason of the presence of the right-angle component of the rotating magnetic field. This component has to be balanced out and it appears to be extremely sensitive to frequency changes. It is possible that with further investigation and study this arrangement could be used. It has the great advantage that the electromotive force in the detecting coil is small and that therefore it can be balanced out by an electromotive force correspondingly small. Since the balance of large electromotive forces makes it correspondingly difficult to balance out their residual, it would appear that this method has some promise.

APPENDIX E

The Steel Hull as a Magnet

A serious limitation of the method of detection described in the body of this report is the requirement that the detecting vessel be of wooden construction. It is obviously highly desirable that any method of detection should be suitable for installation on a destroyer or other type of patrol vessel having a steel hull. The possibility of using the steel hull as the core of the magnet was suggested by Lieutenant-Colonel Mershon early in the investigation. A number of experiments were made at Johns Hopkins University on the submarine models which have been described in other parts of this report.

The models used have been described as S_x and S_y but in these experiments and the accompanying figures and curves they are designated D_{xx} and D_{yy}. A coil of 234

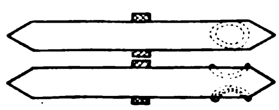

Fig. 19

turns of No. 10 B. & S. magnet wire was placed around the model at its center and excited with 80 volts, 30 cycles of alternating current. Experiments were made with D_{xx} in its original form and also after it had been slit longitudinally, *i. e.*, along one element through its entire length.

The detecting coils used were about 1 ft. in diameter and had 300 turns each. They were flexible so that they could be fitted closely to the sides of the model. In one arrangement two of these coils were balanced against each other, one being placed on each side of the model near the bow, as indicated in Fig. 19.

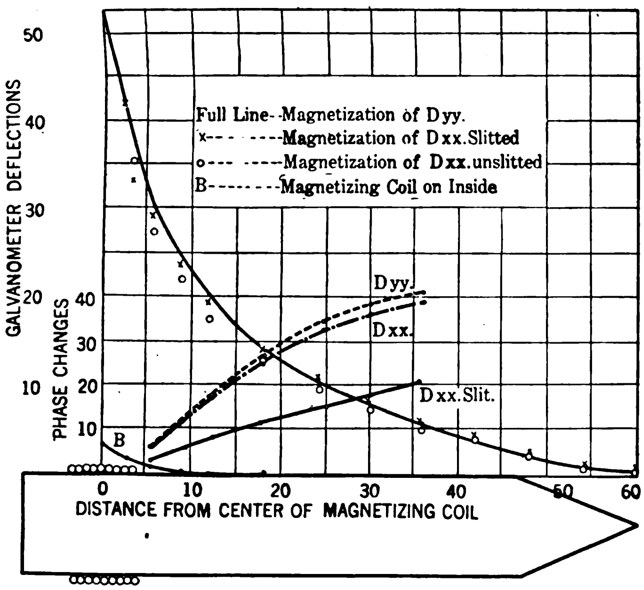

Fig. 20—Magnetization of Destroyer

The distribution of the magnetic flux over the length of the model is shown in Fig. 20, where the alternates represent the electromotive force in a test coil located at different positions along the length. The distribution is seen to be closely the same for models of different thickness and also for the model which was slit from one end to the other along one element.

An interesting and important feature, in its bearing on the use of the hull as a magnet, is the variation in

phase of the flux in passing along the length. The phase of the electromotive force in the exploring coil could be determined simply by the rectifying commutator and detecting instrument. The total variation in phase of the main flux passing from the magnetizing coil to the end of the model was found to be 46.5 deg. for D_{xx}, 23.4 deg. for D_{xx} slit, and 48 deg. for D_{yy}. This variation of phase is shown in the smaller curves of Fig. 20.

The serious limitation of the use of the hull as a magnet, as indicated by the experiments, is in the diffculty of maintaining a satisfactory balance in the

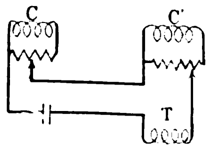

Fig. 21

detecting circuit. Several methods of balancing and disposition of coils were tried as follows:

1. With the coils in the position of Fig. 19, one or both coils were shunted with resistances, taps on which afforded the voltage changes required for balancing. (See Fig. 21, in which T is the primary of the transformer feeding into the amplifier and detecting instrument). The phase changes necessary were obtained by moving one or both of the coils lengthwise over the surface of the hull. With the coils in the positions shown in Fig. 19, this gave the best of all the balances studied in these tests.

2. The detecting coil was placed near the end of the destroyer in the position indicated in Fig. 22. In this

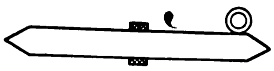

Fig. 22

case the attempt was made to set the coil parallel to the field and so obtain a minimum e. m. f. No position of zero e. m. f. was found and in fact the right angle component of the rotating field was so great that it was not possible to secure a balance in this way.

3. An attempt was made to balance a coil placed round the bow of the destroyer against portions of one placed at the center. It seemed possible that the submarine to be detected might cause a variation of some magnitude in the normal balance of two such coils. The arrangement was not practicable, however, on account of the serious phase difference between the electromotive forces in the two coils.

In all cases it was tedious to obtain a workable balance. The great difficulty was found to lie in the rapid variation of phase as between different positions of the coil along the side of the hull. If the position of the coil was varied to correct for phase difference, a large magnitude difference was introduced at the same time. The best balances which were obtained were very sensitive to variations of frequency and were, in general, less satisfactory than those pertaining to the experiments with a magnet having laminated core and

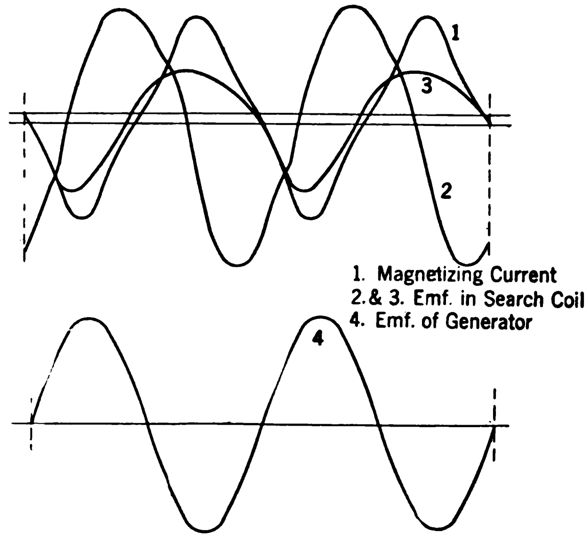

Fig. 23—Oscillograms of Destroyer Field

distributed winding. The balance was found to be extremely sensitive to changes of temperature. Due to eddy currents the temperature of the hull of the model rose considerably to the center, tapering off towards the ends. A glass of water thrown on one side of the hull caused a violent upset of the balance.

A part of the trouble with the balancing was found to lie in the presence of harmonics in the electromotive forces in the detecting circuit. Fig. 23 shows in curve 1 the magnetizing current, curve 2, the electromotive force in the exploring coil when placed around the hull

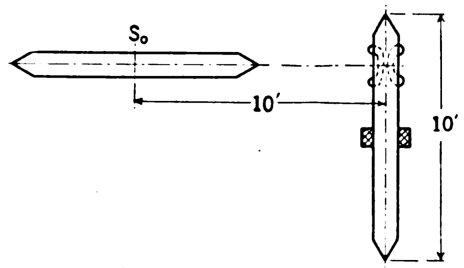

Fig. 24—Relative Positions of Destroyer and Submarine

near the magnetizing coil, and curve 3 the electromotive force in the exploring coil when flattened against the side of the model near the bow. Curve 4 shows the electromotive force of the generator. These curves were all closely copied from oscillograms. In the experiments the harmonic components present were eliminated by the use of a filter.

On account of the difficulty in balancing, the maximum sensitivity in amplifier and detecting instrument could not be used. A number of rough detection

observations were taken, however, of which the most promising were in the relative positions shown in Fig. With S in the position shown, and 10 ft. between centers and detecting coils flattened against the side, the following readings were obtained:

With D_y	30 divisions
With D_y	20 divisions

Using the 2000-turn coil, C_1, as used in the experiments with the magnet, the coil being set parallel to the field on the deck of the destroyer, as shown in Fig. 22, with S at 10 ft., the deflections were for D_{zz} 35 divisions, and D_{yy} 50 divisions.

The experiments with the magnetized model appear not to offer any very great promise for the use of this method. It is probable that the most promising direction in which further study of the method could be made would be in a more uniform magnetization of the hull by, applying additional coils further away from the center, and working the hull at a much lower flux density. In this way there should be less trouble with differences in phase in the balancing coil and also less possibility of disturbances due to temperature variations. It is also certain that the problem of balancing would be very greatly facilitated by the use of a variometer by which the electromotive force in the detecting coil could be balanced, thus obviating the necessity of obtaining a balance by moving a balancing coil.

APPENDIX G

Magnets and Coils

Magnet M_1. This magnet, used in the laboratory tests at the Johns Hopkins University, has been described, and the general method of applying the exciting winding is shown in Fig. 5. The purpose of the multiple winding is to increase the effective length of the magnet and, as far as possible, to prevent variations in this effective length with variation of frequency and voltage.

The distribution of flux in this magnet is indicated approximately in Table 4, in which the first column gives the distance of an exploring coil from one end of the core, and the second column the corresponding voltage induced in this coil. The figures show that the flux is fairly uniform over the whole length of the core, falling off rapidly, however, for positions outside the ends of the magnetizing winding.

Magnet M_2. This magnet was designed by the manufacturer, to give the largest possible magnetic moment with an excitation of 26 kv-a. at 30 cycles. It has a distributed winding with multiple connection of the same general character as that of magnet M_1, the number of coils, however, 266, being much greater. Data as to the number of turns, size wire and dimensions of the respective coils have not been given by the manufacturer. The whole winding is imbedded in weather-proof compound with protective covering.

The pole pieces of the core are relatively longer than in the earlier magnet M_1, thus reducing the amount of copper necessary in the end coils. The laminated core is built up around a wooden cylinder and the cross section of iron is not given. The outside diameter of the combined wooden and iron core, which is circular in cross section, is about 1 ft. The completed magnet is mounted on saddles in a strong and rigid wooden frame.

TABLE IV
DISTRIBUTION OF MAGNETIC FLUX IN MULTIPLE WOUND MAGNET M_1

Distance from one end—inches	Volts in exploring coil
1	3.22
6	5.05
11.2	4.80
15.7	4.90
22	4.84
27.7	4.84
33.5	4.84
39.2	4.70
45.2	4.75
51.2	4.71
58.2	4.70
61.7	4.82
65.7	4.95
71	2.95

Additional data on Magnet M_1 are given in Table 5.

The electric and magnetic constants are given in Table 5.

Magnet M_3. This magnet differs from magnet M_1 principally in its relatively longer pole pieces, the object being to still further reduce the excitation required. As a result, this magnet required a smaller kv-a. consumption and had a greater magnetic flux and magnetic moment than M_1. Its length was about as great as could be comfortably handled in various positions on the deck of S. C. No. 326.

TABLE V
MAGNET DATA

	M_1	M_2	M_3
Length of core	6 ft.	18 ft.	9 ft.
Length of winding	5 ft. 9 in.	14 ft.	6 ft.
Number of coils	28	266	6
Turns per coil	52	..	104
Effective length of M	5 ft. 10.5 in.	16 ft.	7.5 ft.
Cross section, sq. in.	8.81	..	7.7
Equivalent radius	1.65 in.	..	1.57 in.
Rated excitation: Volts	22.6	115	70
Rated excitation: Amperes	200	226	45
Rated excitation: Kv-a.	4.52	26.0	3.15
Power Factor	0.2	0.091	0.13
Total flux	342,500	2,160,000	510,000
Moment C. G. S. units	6.13×10^7	105.2×10^7	11.5×10^7
Weight	386 lb.	4000 lb.	420 lb.

Detecting and Balancing Coils. The data pertaining to the three detecting coils used in the three main divisions of the work are assembled in Table 6. The largest coil C_2, was built by the Westinghouse Electric & Mfg. Co. and was rigidly mounted in a wooden

framework. The winding was thoroughly water proof and enclosed in a protective wooden covering. This coil was designed for out-of-door service.

The detecting coil, C_3, was located in the small forehold of the chaser. This coil had to be wound by hand, its wooden form having been constructed outside and then assembled in place. Owing to the limited space, the winding of this coil was a tedious matter. However, when completed the substantial wooden form and its proximity to the timbers forming the frame of the ship offered a ready means for thoroughly bracing it in position. It contained approximately 900 lb. of No. 13 double cotton-covered magnet wire and was suitably protected against moisture and damage.

A variety of balancing coils was used in different stages of the work. In the experiments in the laboratory and on S. C. No. 326 three coils were used, all having the same dimensions as those of detecting coil C_1, but having 2000, 1000 and 306 turns, respectively. The balancing coil C_2' was of special weather-proof construction, as described for detecting coil C_2. It was three feet in diameter and had 530 turns. It was provided with a worm gear for rotation about a diameter as a vertical axis and also had a gear for a short rectilinear translation. Both of these features were for the purpose of accurate adjustment in balancing. All metal parts were of brass and the entire coil with its adjustment was mounted in a substantial wooden framework.

TABLE VI
DETECTING-COIL DATA

Coil		C_1	C_2	C_3
Diameter	Outside	9.5 in.	85.5 in.	31.25 in.[1]
	Inside	5.75 in.	82.5 in.	47.7 in.[1]
	Average	7.625 in. / 0.635 ft.	7.0 ft.	3.29 ft.[1]
Axial thickness		1.25 in.	3 in.	5.25 in.
Depth of winding		1.87 in.	2.93 in.	7 in.
Volume in cu. ft.		0.0325	1.344	2.63
No. of turns		2000	1308	5145
Resistance		70 ohms	60.07 ohms	99 ohms
Inductance		1 henry	8.22 henrys	53 henries[2]
Weight		9 lb.	1500 lb.	1100 lb.

1. Estimated from dimensions of hexagonal coil.
2. Calculated by means of Doggett's formula.

APPENDIX H

DETECTING AND MEASURING INSTRUMENTS

In the early stages of the work, when sensitivity was a desideratum, suspension-type D'Arsonval galvanometers were used as detecting instruments. It was realized, however, that such an instrument could not be used on shipboard, and as soon as the amplifying equipment was available, the instruments were abandoned. At one time the commutator was suspected as a possible seat of troubles in balancing the detecting circuit. A unipivot type of electro-dynamometer was therefore tried for direct measurement of the signal in the detecting circuit as an alternating current. Experiments with this instrument, however, gave indication that the disturbances in question were due to other causes. Furthermore, the sensitivity of the electro-dynamometer was lower than that of the most suitable D'Arsonval instrument available and offered certain difficulties in the process of balancing and detecting circuit, notably the steps necessary for eliminating the residual or out-of-phase component.

A further effort in the direction of increased sensitivity without the commutator was made in a series of experiments, using an Einthoven string galvanometer. The aim here was to reduce, as far as possible, the number of stages of amplification necessary. Two strings were furnished with this instrument, one of silver and the other of silver quartz. The extreme value of 3.5 times 10^{-16} watts direct current per division of sensitivity was claimed for the instrument using the quartz string.

As compared with the commutator and continuous-current galvanometer, the Einthoven string galvanometer is subject to the following limitations: With the former combination, in the process of balancing, any out-of-phase residual which may be left in the detecting circuit is chopped up by the commutator and appears, if at all, only as a slight vibration of the needle in its zero position. The same statement may be made with reference to any harmonic disturbances which may be present. With the string galvanometer, both the residual and the harmonic will produce a vibration of the string in exact proportion to their intensities. In the experiments with the string galvanometer, these residuals are necessary to produce deflections equal to that pertaining to a strong signal, this sets a definite limit to the sensitivity that may be used with the string galvanometer. A number of rough detection experiments were made, but it was found that the limits mentioned resulted in very much lower distances of detection than found in the case of amplifier, commutator, and continuous-current galvanometer. There remains the possibility of filtering out the harmonics using one or two stages of amplification, and so making use of the extreme sensitivity of this type of instrument. However, it appears probable that the process of balancing would have to be accomplished with the use of other equipment and there is always the question of the behavior of such an instrument on shipboard.

Two instruments of special type were constructed by the Weston Electrical Instrument Co. They were described as Weston No. 2 and No. 3. Instrument No. 2 was found to be not suitable on account of the delicacy of its suspension. Instrument No. 3 was designed especially to dampen out, as far as possible, irregular motions of the galvanometer needle in its position of balance. This instrument, therefore, was heavily damped and its moving part had a relatively high moment of inertia. The weight necessary, and

the consequent force per unit area on the bearings, puts a low limit to the moment of inertia of a sensitive pivot coil instrument; consequently, in this instrument an attempt was made to improve the balance conditions by the use of high and variable damping. This was accomplished in the two-pivot special Weston galvanometer No. 3, by electromagnetic excitation of its field. The instrument had the following characteristics:

Sensitivity,	5.7×10^{-8} amperes per division
Moment of inertia of coil,	2 g. cm.[2]
Undamped period,	1.65 seconds
Interval shunted with 80,000 ohms,	7 seconds
Interval when connected to last stage of amplification and with field fully excited,	80 seconds

By sacrificing some sensitivity, the extremely long interval mentioned, when connected for testing, could be reduced by reducing the field excitation. For the same sensitivity of detection the instrument could be used with one stage of amplification less than that pertaining to the instrument which was used for practically all the other tests. It showed no other decided advantage over the latter instrument which is described below. The possibility of using one less stage of amplification offers some advantage and the instrument was used in a large number of tests. However, it was not as rugged as the instrument next to be described and which supplanted the Weston instrument in all of the later tests on shipboard.

Best Form of Detecting Instrument. The most satisfactory detecting instrument of all was a Siemens & Halske, double-pivot, D'Arsonval type, portable needle galvanometer. This instrument had a central zero and a complete scale of 25 one-millimeter divisions on each side. Its resistance was 100 ohms and its sensitivity 10^{-6} amperes per division. Its critical damping resistance was 90 ohms. This galvanometer withstood all the hard usage of over a year of experiment, and was continuously subjected to various forms of accidental unbalancing, resulting in excess currents, and to the many extreme manifestations of "wiggles" and "shakes" of the needle arising from unforeseen unbalanced resultants, harmonics and extraneous disturbances amplified several hundred times. It had a clear and open scale for direct reading and was in every way superior to all other instruments tried, from the standpoint of convenience and rugged construction. At the end of the experiments its sensitivity was found by test to be unimpaired. Efforts were made to find an instrument of the same general type which would have a higher sensitivity, but when increased sensitivity was found it developed that it was at the sacrifice of either length of scale or substantial construction.

Telephone Receiver as Detector. A number of tests were made with telephone receivers in place of the commutator and galvanometer. Obviously 30 cycles is too low a frequency for audibility. Consequently in order to use the telephone receiver it is necessary to interrupt at sufficiently high frequency the current constituting the signal from the detecting circuit. This was accomplished by placing in series with the telephone instrument at the output end of the amplifier a "chopper," the speed of which could be adjusted for any desired pitch tone for the telephone. Three different forms of chopper were tried, (a) simple interrupter, (b) condenser chopper with sliding contacts and (c) condenser chopper without sliding contacts. All were relatively small machines driven by direct-current motors of variable speed. No further description of these choppers need be given here, as no promising results were obtained from any of them. The invariable trouble was that even at low sensitivity, as regards amplifier and detecting instrument, it was found practically impossible to balance for zero noise in the receiver. Moreover, it was found that under best conditions as to quietness, the electromotive force in the detecting circuit necessary to give a signal was considerably in excess of that required to give a full scale deflection on any one of the galvanometers as detector.

No special study was made of the characteristics of the telephone receiver itself, but four or five different receivers collected from the laboratory telephone and radio equipments were tried. The fact that it was found impossible to eliminate sound in the balanced condition, even with low sensitivity equipment led to the conclusion that this was not the most promising direction in which to look for a higher sensitivity. Moreover, the telephone has in common with the Einthoven galvanometer the disadvantage that it needs an auxiliary equipment for balancing, nor does it give a quantitative indication.

CHEAP WIRELESS TALK ACROSS OCEAN

Signor Marconi prophesies that in the immediate future conversations between Great Britain and the United States will be carried on by wireless telephones and that the price will not be more than 14 cents for one minute.

The great inventor said that he spoke direct to Canada from London and he added:

"It is only a matter of time when we shall be able to talk to New York from London. Already we have carried out many successful experiments between London and the Continent, and we hope that we shall be able soon to announce the installation of a world-wide wireless telephone system in all countries interested. Our plans are developing rapidly."

Transoceanic conversations will be carried on through an ordinary telephone, the exchange being connected with the wireless stations at the receiving end and the same methods will be followed.

Signor Marconi already has applied for permission to erect a station in Norway to demonstrate his ability to talk across large expanses of water.—*Telephone Engineer.*

Magnetic and Electrical Properties of Iron-Nickel Alloys

BY T. D. YENSEN

Research Metallurgist, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Part I. This investigation was undertaken to determine whether any iron-nickel alloys could be found having a higher saturation value than pure iron. Alloys were prepared containing 0-100 per cent Ni.

Pure Fe-Ni alloys do not forge readily, and to make them forgeable it is necessary to add alloying elements like Mn or Ti.

The results show that the saturation value decreases slowly with increase in Ni content up to 20 per cent Ni; then rapidly to 30 per cent; again rises rapidly to 50 per cent and falls off gradually toward 100 per cent Ni. At no point does it exceed that of pure iron.

For values of H between 100 and 400 the permeability is about 5 per cent higher for 6 to 8 per cent Ni than for pure iron, but this advantage is offset by the large increases in hysteresis loss.

Alloys containing 35 to 70 per cent Ni have high permeability at low and medium densities and low hysteresis loss, the highest permeability occurring for 50 per cent.

30 to 50 per cent alloys are characterized by a nearly straight line B-H curve from the origin to B = 2000 to 4000 gausses and also by low retentivity and coercive force, properties which are of value in connection with certain electromagnetic meters.

Part II. Previous investigations on commercial iron-nickel alloys have shown that 25 to 35 per cent alloys have irreversible magnetic and electrical transformation points occurring below ordinary temperatures. The present investigation confirms these results for pure alloys. A 30 per cent alloy, annealed and cooled to room temperature, had its saturation value, $4\pi I_s$ increased from 2500 to 17,800 gausses and its electrical resistance decreased from 81 to 32 microhms per cu. cm. after being cooled to liquid air temperature and reheated to room temperature. Alloys containing 15, 35 and 50 per cent nickel showed practically no change after the above treatment. After allowing all transformations from the austenitic state to the α state to take place the curves for $4\pi I_s$ and for electrical resistances both have definite cusps for 34.5 per cent nickel, corresponding to the compound Fe_2Ni, thus giving evidence of the existence of this compound. It is pointed out that the irreversible transformation causes an enormous increase in the hysteresis loss.

PART I

Introduction. The discovery of materials having higher magnetic saturation than pure iron is of great importance in connection with dynamo-electric machinery, because it is the saturation value of the material in the teeth of the armature that determines to a large extent the size of the machines. If the saturation value could be raised 10 per cent, this would mean that the length of the armature—and consequently the field and frame—could be decreased by approximately 10 per cent, with a resultant large saving in the cost of the machine. Cobalt has been known for some time to increase the saturation value; in the case of the alloy Fe_2 Co by as much as 10 to 13 per cent[1]. At high inductions the author has shown[2] that the permeability of Fe_2 Co may be as much as 25 per cent higher than that of pure iron. This alloy would therefore seem to be very suitable for the purpose mentioned were it not for its high cost. Efforts have consequently been made to discover less expensive materials with properties similar to those of Fe_2 Co.

Nickel has been suggested as a possible substitute for Co, in spite of the fact that according to Weiss[3] nickel lowers the saturation value of iron. Burgess and Aston[4] prepared a large number of alloys ranging from 0–100 per cent Ni and among these there were one or two alloys having a slightly higher permeability at high inductions than pure iron. The composition of these alloys was in the neighborhood of 5 per cent Ni. These results and certain others obtained with low nickel steels prepared commercially made it desirable to investigate carefully the possibilities in the direction indicated. Alloys were consequently prepared from the purest materials obtainable and by the most approved method known to yield pure alloys.

Preparation. The alloys were made by melting the desired proportions of electrolytic iron and electrolytic nickel placed in magnesia crucibles in an Arsem type vacuum furnace under pressure of 1 to 2 mm. mercury. Chemical analysis of the above materials gave the following results:

Element	Electrolytic Iron	Electrolytic Nickel
S	0.003 per cent	0.006 per cent
P	Trace	0.001
C	0.014	0.030
Mn	Trace	Trace
Si	Trace	0.040
Cu	Trace	.....
Al	0.005	.....
Fe	99.978 (by diff.)	0.250
Ni	.....	99.673 (by diff.)

The first attempts that were made to forge the ingots

To be presented at the Boston meeting of the A. I. E. E., April 9, 1920.

1. Weiss: Electromagnet with Ferro-cobalt pole pieces. *Comptes Rendus* 156, p. 1970, June 30, 1913. *Trans. Faraday Soc.* 8, p. 149, 1911-12.

Yensen: Magnetic Properties of the Iron-cobalt alloy Fe_2 Co, *Gen. Elec. Rev.*, 18, p. 881 Sept. 1915. PROC. A. I. E. E., 34, p. 2463.

Kalmus and Blake: Magnetic Properties of Cobalt & Iron-cobalt alloys, *Can. Dept. of Mines, Mines Branch, Report* 413, 1916.

Becket: Alloys of Iron and cobalt, U. S. Patent No. 1, 247,-206, Nov. 1917.

2. Loc. Cit.

3. Loc. Cit.

4. Magnetic and Electrical Properties of Iron-nickel alloys, *Met. & Chem. Engr.* 8, p. 23, Jan. 1910.

revealed the fact that pure iron-nickel alloys do not forge very well at ordinary forging temperatures. Up to 8 per cent Ni, and in rare cases with higher nickel contents, fairly good forgings were obtained by forging at a dull red heat, but not by forging at a bright red heat. In other cases the alloys would forge at a black heat, or even cold, while some alloys could not be forged under any conditions. In order to obtain

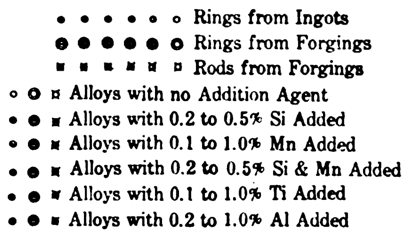

Fig. 1—Key to Point-Notation of Iron-Nickel Alloys

pure iron-nickel alloys in the form of test pieces it was, therefore, necessary in some cases to machine rings directly from the ingots. Forgeable alloys were obtained by means of certain addition agents. Ti and Mn worked successfully for this purpose, while Si, Al and Mg had no effect. The amounts of Ti and Mn required varied from 0.2 per cent for 10 per cent Ni to 1.0 per cent for 50 per cent.

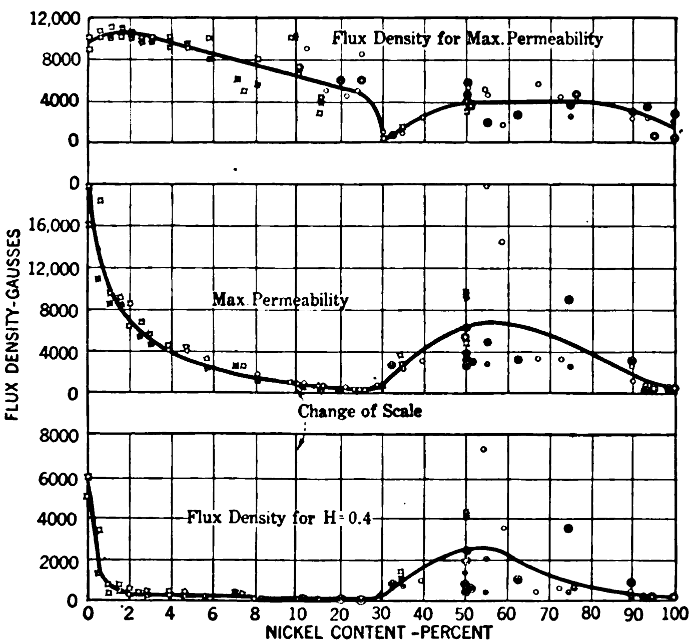

Fig. 2—Flux Density for Maximum Permeability

Three kinds of test pieces were prepared:

1. Rings from ingots, 2.46 cm. (31/32 in.) outside diam., 1.83 cm. (23/32 in.) inside diam. and 0.95 cm. (3/8 in.) long.

2. Rings from forgings, 2.46 cm. (31/32 in.) outside diameter, 1.83 cm. (23/32 in.) inside diameter and 0.95 cm. (3/8 in.) long.

3. Rods from forgings 1.27 cm. (1/2 in.) diam. and 30.5 cm. (12 in.) to 35.5 cm. (14 in.) long.

The annealing was done at 900 to 950 deg. cent, in rare cases at higher temperatures, in a vacuum furnace, under a pressure of less than 0.1 mm. of mercury, the test pieces being buried in granulated MgO, and the temperature measured by means of a Pt-Pt Rh thermo couple. The cooling was extended over a period of 24 hours and was done at a rate of approximately 30 deg. per hour.

Testing. The magnetic testing of the rods was done by the Burrows compensated double bar and yoke

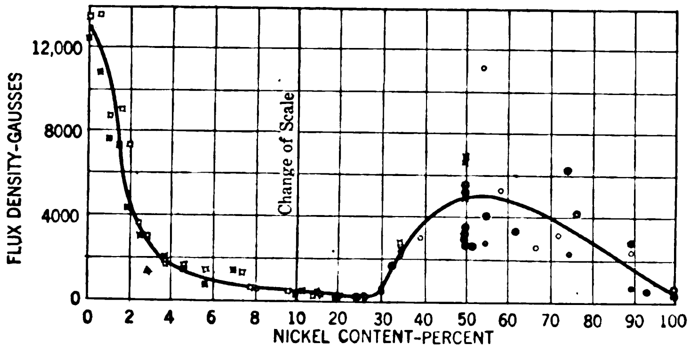

Fig. 3—Flux Density for $H = 1$

method,[5] being the most approved method thus far developed for rods. The rings were tested by means of the ordinary two-winding method, no other method being either simpler or more accurate.

Results. The results are embodied in the following tables and curves. No attempt has been made by means of separate curves to show the effect upon the properties of pure iron-nickel alloys by the addition of other elements necessary to make them forgeable.

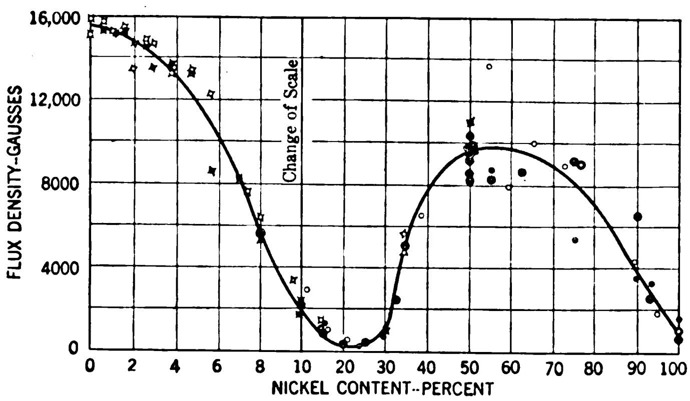

Fig. 4—Flux Density for $H = 4$

In most cases the effect of nickel upon iron is so marked as to obscure any effect due to other elements. Only in the region from 50–70 per cent are the alloys markedly susceptible to mechanical and heat treatment and to other alloying elements, and in this region there is much uncertainty as to the magnetic proper-

5. Bull. *Bur. of Stand.* Vol. 6, No. 1, Rep. No. 117. Bull. Eng. Exp. Sta. Univ. of Ill. No. 72 (1914), No. 83 (1915), Trans. A. I. E. E., 33, I. 451 (1914), 34, II., 2601 (1915).

TABLE I

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS ELECTROLYTIC IRON AND NICKEL, MELTED AND ANNEALED IN VACUO

Specimen No.	Ni-content per cent	Kind testpiece	Annealing Temp. deg. cent.	Electrical resist. microhms per cu. cm.	Max. permeability	β for μ_{max}, gausses	Density, β, in Kilogausses for H = 0.2	0.4	1	4	20	100	400	Satur. value, $4\pi I_s$	Hysteresis loss for β = 10,000, ergs/cu. cm./cycle	Retentivity for β = 10,000, gausses	Coercive force for β = 10,000 gilberts/cm.
2 Ni 201	0.50	Forged Rods	920	11.5	18,200	10,000	0.6	3.4	13.6	15.7	16.5	18.3	21.2	22,700	1,175	9,200	0.39
203	1.01[1]	" "	920	12.7	9,350	11,000	0.2	0.9	8.7	15.2	16.2	18.4	21.4	22,500	..	..	..
205	1.48	" "	900	13.8	9,100	10,000	0.2	0.8	9.0	15.4	16.7	18.6	21.5	22,700	..	..	..
207	1.96	" "	940	14.9	8,200	10,000	0.2	0.6	7.2	13.4	16.7	18.6	21.6	22,600	1,900	8,700	0.65
209	2.44	" "	940	16.1	6,680	10,000	0.15	0.4	3.6	14.9	16.7	18.75	21.65	22,600	..	..	..
211	2.84[1]	" "	920	17.1	5,650	10,000	0.15	0.4	3.0	14.6	16.8	18.6	21.65	22,700	..	..	..
213	3.85	" "	902	19.4	4,350	10,000	0.1	0.2	1.6	13.2	16.4	18.6	21.8	22,360	3,300	8,300	1.10
215	4.62[1]	" "	902	20.3	4,100	9,000	..	0.3	1.6	13.3	16.7	18.7	21.2	22,300	..	..	..
294	5.68[1]	Ring from ingot[2]	923	..	4,500	3,220	0.2	0.6	4.5	11.0	14.5	16.7	19.1	20,000	2,440	6,600	0.80
217	5.67	Forged rods	920	22.0	3,300	10,000	..	0.1	1.3	12.2	16.7	19.0	21.7	22,400	..	..	..
219	7.33[1]	" "	1,064	24.8	2,130	5,000	0.1	0.3	1.2	7.6	16.2	19.1	21.6	22,600	4,225	5,700	1.45
221	8.00	" "	920	25.2	1,710	8,000	..	0.1	0.5	6.4	15.4	19.1	21.6	22,100	..	..	..
237	9.61[1]	" "	920	27.1	810	10,000	..	..	0.3	3.4	13.0	18.7	21.0	21,200	9,270	5,600	3.3
295	11.10[1]	Ring from ingot	923	..	855	8,900	..	0.1	0.3	2.9	13.3	19.1	21.5	22,000	9,450	5,800	3.70
225	14.92[1]	Forged rods	960	29.8	460	3,000	..	..	0.2	1.5	8.2	17.3	21.0	21,600	12,500	4,200	5.00
296	15.87[1]	Ring from ingot	923	..	475	5,000	..	..	0.2	1.1	8.1	15.2	19.7	22,300	13,080	4,250	5.10
297	21.03[1]	" " "	923	..	276	4,500	..	..	0.1	0.5	5.4	15.2	20.0	22,200	30,000	5,200	13.00
233	34.81[1]	Forged rods	950	80.4	3,600	1,000	0.8	1.4	2.8	5.7	10.0	12.0	12.2	..	910	2,400	0.40
298	38.92[1]	Ring from ingot	923	..	3,060	2,300	0.3	1.0	3.0	6.4	10.4	12.4	12.2	11,900	1,030	2,400	0.45
2,102	54.08[1]	" " "	923	..	19,600	5,200	3.6	7.3	11.1	13.7	15.6	15.6	16.0	15,600	580	7,600	0.18
2,101	57.99[1]	" " "	923	..	14,500	1,888	2.6	3.6	5.2	7.9	12.2	13.8	14.2	13,800	194	3,400	0.14
2,100	66.96[1]	" " "	923	..	3,200	5,500	0.2	0.4	2.6	10.0	13.1	13.6	13.9	13,500	1,330	3,400	0.56
2,104	72.63[1]	" " "	923	..	3,230	4,200	0.2	0.6	3.1	8.8	12.4	12.6	12.9	12,500	922	2,500	0.40
285	75.80[1]	Ring from forging	931	..	4,230	4,400	0.1	0.7	4.2	9.0	11.1	11.4	12.0	12,000	627	2,350	0.34
															(β=4000)	(β=4000)	(β=4000)
2,103	89.83[1]	Ring from ingot	923	..	2,310	2,200	0.2	0.5	2.2	4.3	5.7	6.2	6.2	6,000	592	2,150	0.53
287	95.05[1]	Ring from forging	931	..	500	560	..	0.1	0.5	1.9	5.6	7.0	7.6	7,410	3,015	2,450	2.85
288	99.88[1]	" " "	931	..	400	400	..	0.1	0.4	1.0	4.4	6.0	6.8	6,550	5,650	2,450	5.20

1. As per Chem. Anal. other alloys as per amount Ni added.
2. Low sp. gr.—not plotted.

ties at low flux densities. This is plainly seen in Figs. 2, 3, 4 and 10 for maximum permeability, for permeabilities for H = 0.4, 1 and 4, and for hysteresis loss, respectively. In spite of this uncertainty all points have been plotted together and the curves

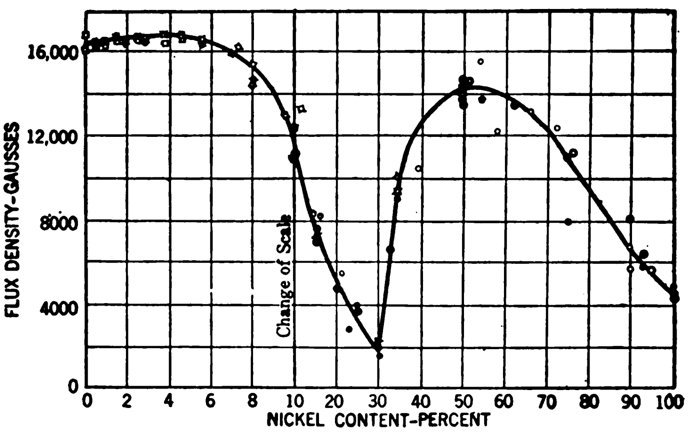

FIG. 5—FLUX DENSITY FOR H = 20

drawn through the centers of density of the point. The curves thus obtained for H = 0.4, 1, 4, 20, 100, 400 and for the saturation intensity, $4\pi I_s$, have all been replotted in Fig. 9 showing at a glance the variation in permeability for various magnetizing forces with variation in nickel content. These curves might be termed the magnetic iso-gilberts for the iron-nickel alloys. To this set of curves the following general statements can be applied:

1. The saturation intensity, I_s decreases slightly—not more than 1 or 2 per cent—from pure iron to 20

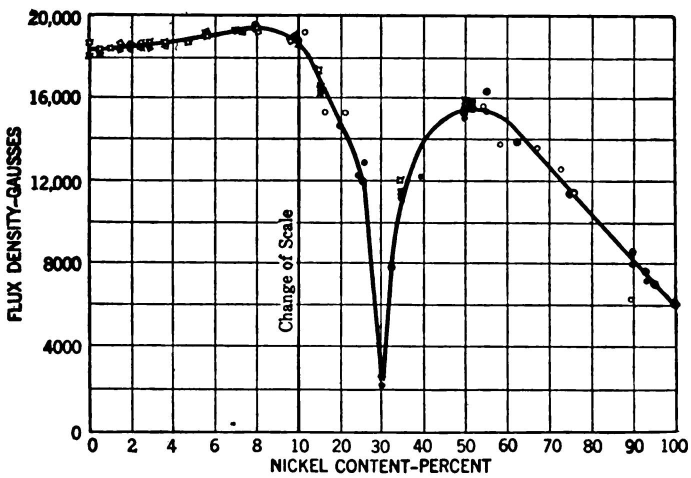

FIG. 6—FLUX DENSITY FOR H = 100

per cent nickel. Between 20 and 30 per cent nickel I_s decreases to one-tenth of its previous value, increases again rapidly beyond 30 per cent, reaches a maximum for 50 per cent nickel and finally decreases

gradually toward 100 per cent nickel, the value for pure nickel being between 1/3 and 1/4 that for pure iron.

2. The iso-gilberts for high values of H are of the same general shape as that for I_s, except that there is a slight increase—about 5 per cent—in permeability between O and 8 per cent nickel.

30 per cent nickel has been shown to be due to the fact that the magnetic transformation point of these alloys lies below ordinary temperatures. K. Honda in a recently published paper[6] has shown that cooling the alloys in liquid air and then heating them to room temperature raises I_s from the minimum value of about 200 to nearly 1000. At the same time the

TABLE II

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS ELECTROLYTIC IRON AND NICKEL, MELTED AND, ANNEALED IN VACUO. EFFECT OF SI AND MN AS ADDITION AGENTS

Specimen No.	Ni-content per cent	Si-added per cent	Mn-added per cent	Kind Testpiece	Annealing temp. deg. cent.	Electrical resist. microhms per cu. cm.	Max. permeab. μ_m	β for μ_m, gausses	Density, β, in kilogausses for $= H$							Satur. value, $4\pi I$	Hysteresis loss for $\beta = 10,000$, ergs/cu. cm./cycle	Retentivity for $\beta = 10,000$, gausses	Coercive force for $\beta = 10,000$, gilberts/cm.
									0.2	0.4	1	4	20	100	400				
2 Ni 202	0.50	0.2	..	Forged rods	920	12.7	11,000	10,000	0.2	1.4	10.8	15.3	16.4	18.2	21.1	22,500	1,570	9,100	0.52
204	1.00	0.2	..	“ “	900	14.3	8,330	10,000	0.15	0.5	7.6	15.2	16.6	18.4	21.4	22,800	..	..	..
206	1.48	0.2	..	“ “	900	15.1	8,530	11,000	0.2	0.7	7.2	15.3	16.8	18.3	21.6	22,500	..	..	..
208	1.96	0.2	..	“ “	940	16.5	6,060	10,000	0.15	0.4	4.2	14.7	16.6	18.5	21.5	22,500	2,420	8,700	0.80
210	2.44	0.2	..	“ “	920	18.0	5,650	10,000	0.15	0.4	3.0	14.6	16.8	18.4	21.5	22,200	..	..	..
212	2.90	0.2	..	“ “	920	19.1	4,550	10,000	0.1	0.2	1.2	13.4	16.5	18.5	21.4	22,500	..	..	..
214	3.85	0.2	..	“ “	902	20.7	4,500	9,000	0.1	0.3	2.0	13.6	16.9	18.6	21.5	22,500	3,030	8,100	1.02
216	4.76	0.2	..	“ “	920	21.4	4,000	9,000	..	0.2	1.4	13.2	16.9	18.8	21.75	22,800	..	..	..
218	5.67	0.2	..	“ “	920	25.8	2,130	8,000	..	0.1	0.6	8.5	16.4	19.1	21.7	22,240	..	..	..
220	7.00	0.2	..	“ “	1,064	25.7	2,400	6,000	0.2	0.5	1.3	8.1	16.0	19.2	22.0	22,600	3,760	5,400	1.30
273	8.00	..	0.1	Forged rod	900	26.2	1,300	5,200	..	0.1	0.5	5.2	14.4	19.2	21.9	21,800	5,990	5,900	2.36
				“ ring	900	..	1,350	5,400	..	0.1	0.5	5.5	14.6	19.4	22.2	22,700	6,340	5,800	2.20
272	10.00	0.2	0.1	Forged rod	900	28.9	640	6,400	..	0.07	0.2	2.2	12.4	18.5	21.5	21,850	11,200	5,300	4.10
				“ ring	900	..	700	7,000	..	0.05	0.2	2.1	11.1	18.8	21.9	22,200	11,100	5,400	4.30
238	9.52[1]	0.2[2]	..	Forged rods	920	29.6	556	10,000	..	0.1	0.3	2.7	10.6	17.0	19.9	20,400	10,150	5,400	3.90
226	15.0	0.2	..	“ “	960	31.0	450	4,000	..	..	0.2	1.4	7.5	16.5	20.9	21,300	12,300	4,200	5.00
232	30.0	0.2	..	Forged rods	950	82.0	500	250	0.1	0.2	0.4	1.0	2.1	2.6	3.1	2,700	169	200	0.40
				Ring from ingot	1,100	..	570	250	0.1	0.2	0.5	1.0	1.9	2.6	..	..	220[3]	200[3]	0.60[6]
283	32.6[1]	..	1.0	Ring from forging	931	..	2,320	720	0.5	0.9	1.7	3.4	6.5	7.9	8.7	8,570	334[5]	950[5]	0.38[5]
234	34.5	0.2	..	Forged rods	950	81.3	2,780	1,500	0.3	1.1	2.5	4.9	9.2	11.4	11.8	11,410	1,040	2,000	0.40
				Ring from ingot	1,100	..	2,210	1,500	0.2	0.8	2.1	5.0	9.0	11.2	..	..	1,800	1,500	0.80
261	50.0	..	0.75	Forged rod	900	42.8	9,600	2,870	0.9	4.0	6.8	10.9	14.5	15.7	15.9	15,540	810	4,800	0.29
				“ ring	917	..	3,200	4,000	0.2	0.5	2.9	9.1	14.0	15.2	15.7	15,350	1,810	3,600	0.75
262	50.0	..	1.0	Forged rod	900	45.6	9,600	2,870	0.9	4.0	6.8	10.9	14.1	15.1	15.5	14,900	810	4,800	0.29
				“ ring	917	..	6,060	4,000	1.0	2.4	5.5	10.2	14.5	15.4	16.0	15,450	724	2,300	0.30
263	50.0	0.5	0.5	Forged ring	931	..	3,570	4,600	0.3	0.8	3.4	9.3	13.8	15.5	16.3	15,900	2,315	5,300	0.89
264	50.0	0.25	0.5	“ “	900	..	2,940	4,000	0.4	0.8	2.8	8.5	14.2	15.5	15.7	15,800	1,390	2,500	0.60
281	51.4[1]	..	1.0	“ “	931	..	3,110	5,600	0.2	0.6	2.7	9.8	14.7	15.8	16.3	15,960	2,155	4,400	0.80
289	54.9[1]	..	0.5	Ring from ingot	931	..	2,860	4,300	0.1	0.3	2.7	8.7	13.7	14.3	14.8	14,500	1,177	2,550	0.68
				Forged ring	923	..	5,000	2,000	0.8	2.0	4.0	8.2	13.7	15.2	15.4	15,100	579	2,300	0.32
279	62.2[1]	..	1.0	Forged ring	931	..	3,300	2,800	0.3	1.0	3.3	8.5	13.4	13.9	14.5	14,160	1,581	3,700	0.55
290	74.8[1]	..	0.5	Ring from ingot	931	..	2,200	2,200	0.1	0.4	2.2	5.3	7.9	8.8	9.2	8,840	706[4]	2,550[4]	0.68[4]
				Forged ring	923	..	9,000	3,600	1.4	3.5	6.2	9.0	11.0	11.4	11.7	11,300	541	3,650	0.24
291	89.9	..	0.5	Ring from ingot	931	..	1,040	2,400	..	0.1	0.6	3.6	6.7	8.0	8.5	8,210	1,453[4]	2,400[4]	1.42[4]
				Forged ring	923	..	2,660	2,800	0.3	0.9	2.7	6.5	8.0	8.5	8.7	8,300	1,222[6]	2,700[6]	0.60[6]
292	93.3[1]	..	0.5	Ring from ingot	931	..	800	2,400	..	0.1	0.3	3.1	5.8	7.2	7.6	7,230	2,055[4]	2,700[4]	1.8[4]
				Forged ring	922	..	630	3,400	..	0.1	0.3	2.4	6.3	7.6	7.8	7,450	4,480[5]	3,400[5]	2.7[5]
293	99.9[1]	..	0.5	Ring from ingot	931	..	500	2,000	..	..	0.4	1.5	4.7	6.2	6.8	6,490	3,640[4]	2,600[4]	3.2[4]
				Forged ring	923	..	316	2,750	..	0.1	0.4	0.8	4.3	6.0	6.3	6,000	5,870[4]	2,400[4]	5.6[4]

1. As per Chem. Anal. other alloys as per amount added.
2. C—0.061 per cent not plotted.
3. For $\beta = 2,000$
4. For $\beta = 4,000$
5. For $\beta = 6,000$
6. For $\beta = 8,000$

3. For low values of H the iso-gilberts drop rapidly from pure iron and remain very low until the 30 per cent point has been passed; reaching a maximum between 50 and 60 per cent nickel, for which in some cases a permeability has been reached approaching that for pure iron; and finally decreases to very low values for 100 per cent nickel.

The low saturation value occurring in the region of minimum point has been shifted from 28 to 30 per cent to about 34.5 per cent, the latter corresponding to the compound Fe_2Ni.[7]

6. The Thermal and Electrical Properties of Nickel Steels, *Sci. Repts.*, Tohoku Imp. Iniv. 7, pp. 59–66. (1918).

7. By the above treatment the iso-gilberts would, of course, also be changed, and the entire set of curves would appear very differently. This matter is discussed in Part II of this paper.

TABLE III

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS ELECTROLYTIC IRON AND NICKEL, MELTED AND ANNEALED IN VACUO. EFFECT OF Ti AND Al AS ADDITION AGENTS

Specimen No.	Ni-content, per cent	Ti-added per cent.	Al-added per cent	Kind testpiece	Annealing temp. deg. cent.	Electrical resist. microhms per cu. cm.	Max. permeab. μ_m	β for μ_m, gausses	Density, β, in kilogausses for H = 0.2	0.4	1	4	20	100	300	Satur. valve, $4\pi I_s$	Hysteresis loss for β = 10,000, ergs/cu. cm./cycle	Retentivity for β = 10,000, gausses	Coercive force for β = 10,000, gilberts/cm.
2 Ni 236	9.9	0.20	..	Forged rods	920	27.5	605	10,000	..	..	0.2	1.7	11.0	18.9	21.5	22,600	10,700	5,300	4.10
247	15.0[1]	0.20	..	Forged rods	900	30.8	405	4,050	..	..	0.1	1.3	7.3	16.5	20.5	21,600	15,150	4,400	5.70
				" ring	917	..	382	4,000	..	..	0.05	0.9	6.9	16.2	20.2	21,900	13,900	3,900	5.90
248	20.0[1]	0.20	..	Forged ring	917	..	240	6,000	..	..	0.05	0.4	4.8	14.7	19.4	22,200	28,200	4,900	12.00
249	25.0[1]	0.20	..	" "	917	..	187	6,000	..	..	0.05	0.3	3.6	12.0	15.9	18,400	36,900	5,000	15.00
251	50.0[1]	0.50	..	" "	917	..	5,700	4,000	0.6	2.0	5.2	9.8	14.5	15.7	16.0	15,600	852	3,000	0.40
252	50.0[1]	1.00	..	Forged rod	900	47.5	4,960	4,960	0.4	1.3	5.0	9.5	13.9	15.2	15.6	15,200	1,385	4,200	0.62
				" ring	917	..	3,200	3,200	0.4	1.0	3.2	8.2	13.6	15.0	15.6	15,300	1,270	2,600	0.60
2 Ni 240	23.8	..	0.20	Ring from ingot	950	..	200	5,000	..	..	0.03	0.2	2.8	12.1	16.3	19,200	10,860[2]	2,300[2]	12.80[2]
241	25.1	..	0.20	" " "	950	..	172	8,600	..	..	0.05	0.3	3.8	12.9	17.0	19,700	8,950[2]	2,400[2]	10.20[2]
242	29.8	..	0.20	" " "	950	..	400	400	..	..	0.4	0.8	1.5	2.1	2.8	2,860	278[3]	150[3]	0.50[3]

1. Per cent Ni added, alloy not analysed chemically.
2. For $\beta = 4{,}000$
2. For $\beta = 1{,}500$

Fig. 10 shows the variation of hysteresis loss for B = 10,000 gausses with nickel content. As might be expected from the iso-gilberts of the previous curve, the loss increases rapidly even with small additions of nickel, and the loss becomes very high for alloys containing 15 to 25 per cent, reaching a maximum of nearly 50,000 ergs per cu. cm. per cycle for the 25 per cent alloy. Between 30 and 70 per cent the loss is as low or even lower than for pure iron, but above 70 per cent the loss again increases rapidly reaching 20,000 for pure nickel.[8]

Fig. 10 shows the retentivity to decrease with increasing nickel content reaching a minimum of only 200 for the 30 per cent alloy. With further increase in nickel content, the retentivity again increases, reaching a maximum between 50 and 60 per cent nickel.[9]

Fig. 12 shows the variation in electrical resistance checking very closely the results obtained by Burgess and by Honda.[10] The curve has been drawn through the points for pure iron-nickel alloys for all cases in which alloys were available in the form of rods. In every case it will be noticed that the alloys containing a small amount of silicon have a decidedly higher resistance than the alloys without silicon, as

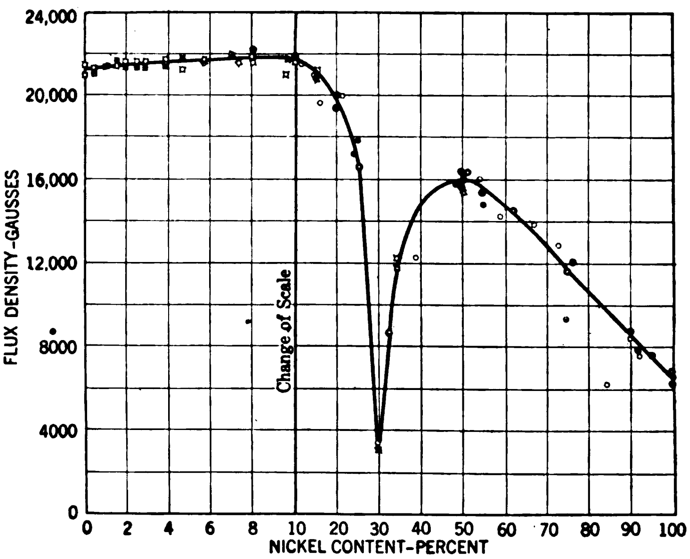

FIG. 7—FLUX DENSITY FOR H = 400

might be expected. The curve reaches a maximum for 30 per cent nickel corresponding to the composition of the alloy having the lowest magnetic saturation value. Honda has obtained a decrease in electrical resistance corresponding to the increase in the saturation value above referred to, by cooling the alloys in liquid air and then heating to room temp-

8. All losses are based on a flux density of 10,000 gausses. In case of the 30 and 80 to 100 per cent alloys having saturation values lower than 10,000 the losses were obtained for as high densities as possible, and the hypothetical loss for 10,000 calculated by means of the formula

$$W_{10} = W_B \left(\frac{10{,}000}{B} \right)^{1.6}$$

Where W_B is the loss actually obtained by test for the flux density B. The 1.6 law may not be strictly applicable in the case of the alloys mentioned, but is believed to be sufficiently accurate for the purpose of comparison.

9. No correction has been made in case the alloy was tested at a lower density than 10,000, but the error is supposed to be small in every case. Examples: 2 Ni 285, containing 75 per cent nickel was tested at 10,000 gausses, showing a retentivity of 2350, while 2 Ni 290, having the same nickel content, tested at B = 4000 gave a retentivity of 2550.

10. Loc. Cit.

erature. For the 30 per cent alloy the resistance decreased from a value of approximately 90 to 30 microhms, whereas no change is shown for the 34.5 per cent alloy corresponding to Fe_2Ni, making this the alloy having the maximum resistance.[11]

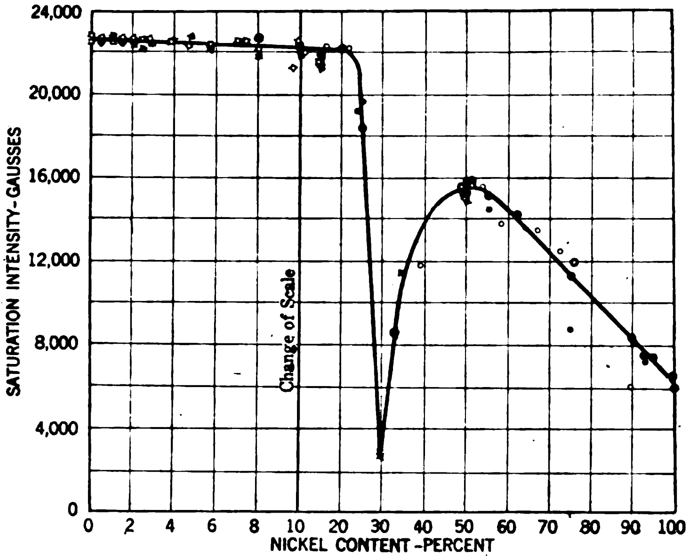

FIG. 8—SATURATION INTENSITY $4\pi I_s$ AND FLUX DENSITY FOR VARIOUS MAGNETIZING FORCES

The specific gravity shown in Fig. 13 was obtained incidentally as a means of obtaining the true cross section of the ring test pieces. The values increase uniformly from 7.9 for pure iron to 8.9 for pure nickel.

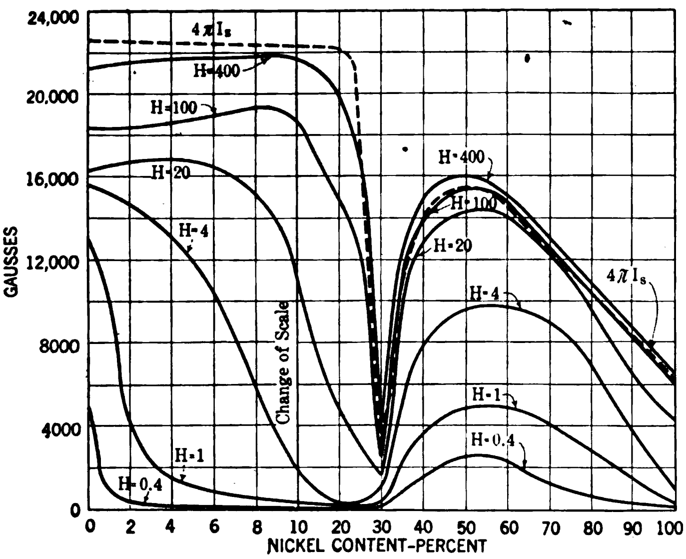

FIG. 9—SATURATION INTENSITY OF MAGNETIZATION $4\pi I_s$

PART II

MAGNETIC AND ELECTRICAL PROPERTIES OF IRON-NICKEL ALLOYS REVERSIBLE AND IRREVERSIBLE TRANSFORMATIONS

Introduction. In Part I of this paper it was pointed out that the properties of alloys in the neighborhood of 30 per cent nickel would be very different after being cooled to liquid air temperature from after being cooled merely to room temperature. It was further pointed out that this difference is due to the fact that these alloys—in addition to the reversible transformation point occurring above room tempera-

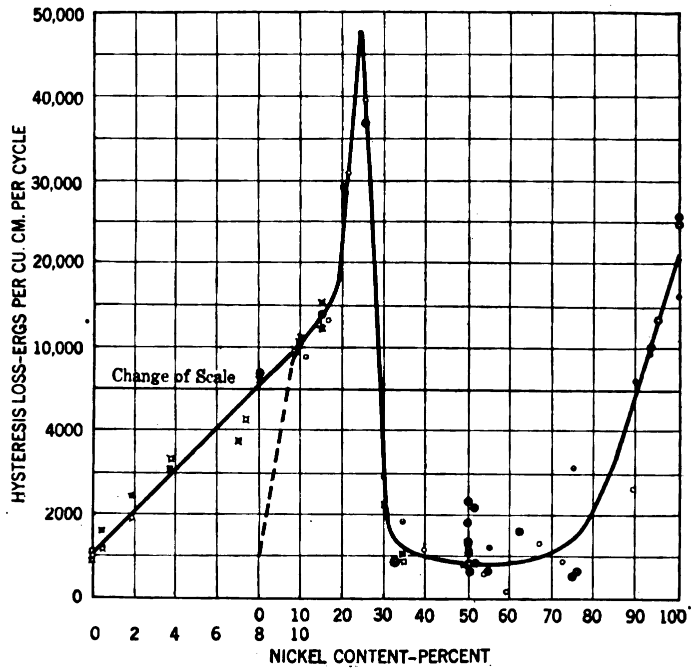

FIG. 10—HYSTERESIS LOSS FOR B = 10,000

ture—have an irreversible transformation point occurring below room temperature. These transformations have been studied a great deal in recent years, the pioneers in the field being Hopkinson (1), LeChatelier (2), Osmond (3), Guillaume (4) and Dumas (5).[12] The alloys investigated by these scien-

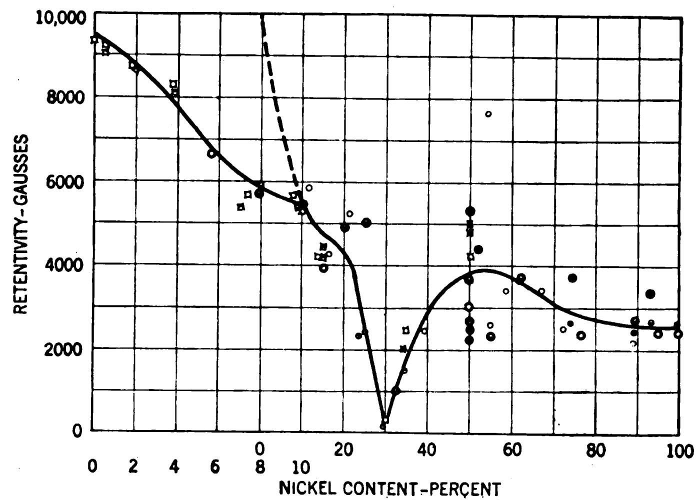

FIG. 11—RETENTIVITY FOR B = 10,000 GAUSSES

11. Further data on this subject is contained in Part II.

12. (1) *Proc. Royal Soc.*, 46 and 47, p. 23, 1889, 48 p. 1., 1890.
(2) *Comptes Rendus*, 90 p. 285, 1890.
(3) *Comptes Rendus*, 118, p. 532, 1894; 121, p. 684, 1895; 128, pp. 306, 1395, 1513, 1899.
(4) *Comptes Rendus*, Jan. 25, April 5, June 18, July 26, 1897.
(5) *Comptes Rendus*, 139, p. 42, 1899, *Jour. Iron & Steel Inst.*, II, p. 225.

tists all contained foreign elements to some extent, particularly carbon and manganese. As a matter of fact manganese was considered an essential constituent, because without it, the alloys could not be forged. It is very unfortunate, however, for the interpretation of the results of the above investigations that these two elements referred to are the ones that affect the transformation points the most. Thus

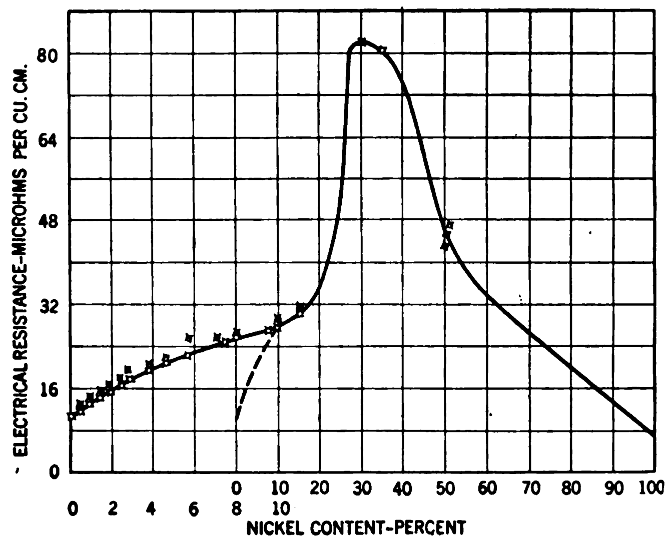

Fig. 12—Electrical Resistance

carbon is 20 times as effective as nickel in lowering the transformation points, and manganese, while less effective in this respect than carbon, still is much more effective than nickel. Dumas[13] realized this

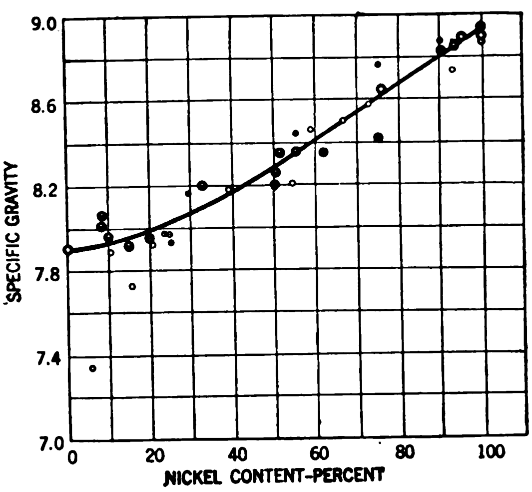

Fig. 13—Specific Gravity

when he stated that "No nickel steel is non-magnetic at ordinary temperatures except steels containing carbon and manganese," and he consequently attempted to keep these elements as low as possible. The results of his experiments are shown in Fig. 14. It will be noted that from 27 to 31 per cent nickel Dumas found both reversible and irreversible transformations.

13. Loc. Cit.

Of the two, however, the irreversible was by far the more intense. The broken curves indicate probable transformations in pure alloys that are too feeble in comparison with the transformations that have already occurred to be readily detected. However, by introducing carbon into the alloys, the irreversible transformation points may be lowered sufficiently

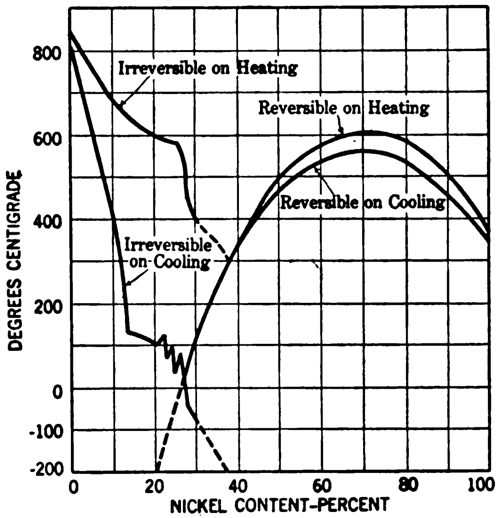

Fig. 14

without lowering the reversible points, to reveal the latter. Dumas cites the example of a 23 per cent alloy, which when pure has an irreversible point on cooling at +75 deg. but apparently no reversible point. By adding 0.85 per cent and 1.41 per cent

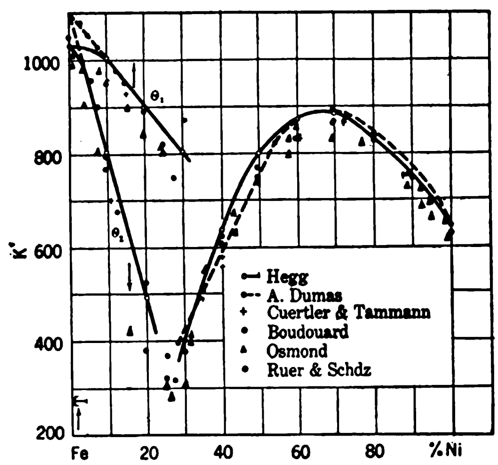

Fig. 15—Absolute Centigrade Temperatures of Magnetic Transformation (Curie Points) for Pure Ferronickels (Hegg)

Mn to this alloy the irreversible point is decreased to −188 deg., and on cooling from 0 deg.—the alloy is now non-magnetic—the reversible point is revealed at −150 deg. On the assumption that the reversible points are unaffected by C or Mn, Dumas concludes that the pure Fe-Ni alloys between 20 and 37 per cent nickel have both reversible and irreversible transformation points.

TABLE IV

MAGNETIC AND ELECTRICAL PROPERTIES OF Fe-Ni ALLOYS REVERSIBLE AND IRREVERSIBLE TRANSFORMATIONS

Condition	Max. permeability, μ_m	Flux density for μ_m, gausses	Flux density (kilogausses) for H (gilberts/cm.) of 1	10	100	400	Saturation value, $4\pi I_s$	Hysteresis loss for $\beta = 10{,}000$—ergs/cu. cm./cycle	Electrical resist.—microhms/cu. cm.	Max. permeability, μ_m	Flux density for μ_m, gausses	Flux density (kilogausses) for H (gilberts/cm.) of 1	10	100	400	Saturation value, $4\pi I_s$	Hysteresis loss for $\beta = 10{,}000$ ergs per cu. cm. per cycle	Electrical resistance, microhms per cu. cm
	30 per cent Ni (2 Ni 232)								Rings	34.5 per cent Ni (2 Ni 234)								
Annealed at 1,100 deg. c. in Vacuo..	560	220	0.4	1.5	2.8					2,210	1,500	2.0	7.2	11.21				
Cooled to —70 deg................	..	..	..	..	..							0.5	5.3	13.1				
Cooled to —70 deg. and heated to + 20 deg.	232	4,650	0.1	2.0	10.3							2.1	7.0	11.1				
Cooled to —185 deg.	279	5,580	0.1	2.3	13.0							0.3	5.3	13.4				
Cooled to —185 deg. and heated to + 20 deg.	244	4,880	0.1	1.9	12.0							0.6	4.7	11.2				
	30 per cent Ni (2 Ni 232)								Rods	34.5 per cent Ni (2 Ni 233 and 234)								
Annealed at 900 deg. c. in Vacuo....	500	250	0.4	1.5	2.6	3.1	2,700	2,230[1]	82	3,200	1,300	2.7	8.0	11.7	12.0	11,500	1,000	81
Cooled to —70 deg. and heated to + 20 deg.	213	4,550	0.1	1.8	10.2	13.4	14,600	31,100	38	..	..	2.6	7.7	11.6	12.0	..	..	80
Cooled to —185 deg. and heated to + 20 deg.	250	5,750	0.1	1.8	12.5	16.4	17,800	..	32	3,120	1,560	2.6	7.6	11.7	12.1	11,710	..	78
	15 per cent Ni (2 Ni 225)								Rods	50 per cent Ni (2 Ni 261 and 262)								
Annealed at 900 deg cent. in vacuo.	460	3,000	0.2	4.9	17.3	21.0	21,600	12,500	30	9,600	2,870	6.8	13.0	15.4	15.6	15,200	810	44
Cooled to —70 deg. and heated to + 20 deg.	494	3,600	0.2	4.8	17.2	21.0	..	..	30	..	..	6.8	12.9	15.2	15.5	..	..	44

1. Calculated from the loss for $\beta = 2{,}000$ by means of the 1.6 law $= W_{10} = W_2\,(10/2)^{1.6}$.

In a recently published circular[14] the Bureau of Standards has compiled all the important data published prior to 1916 relating to iron-nickel alloys and includes an extensive bibliography. Fig. 15 gives the

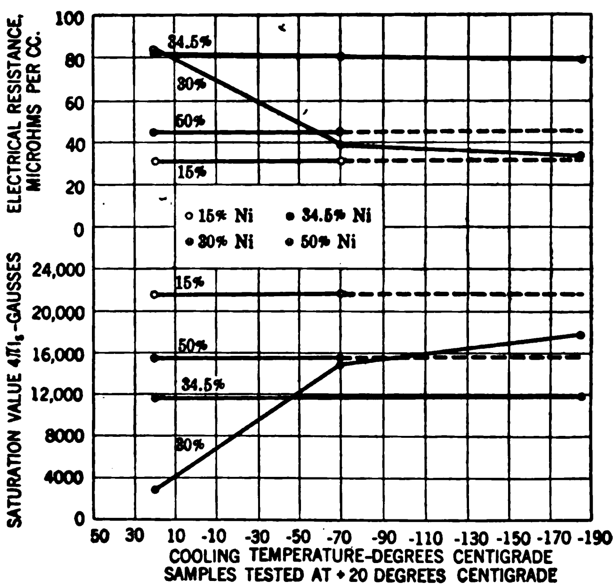

Fig. 16

magnetic transformation according to Hegg reproduced from this circular, giving also points determined by Dumas and by Osmond magnetically, by Guertler and Tammann and by Rurer and Schuz metallographically and by Boudouard thermoelectrically.

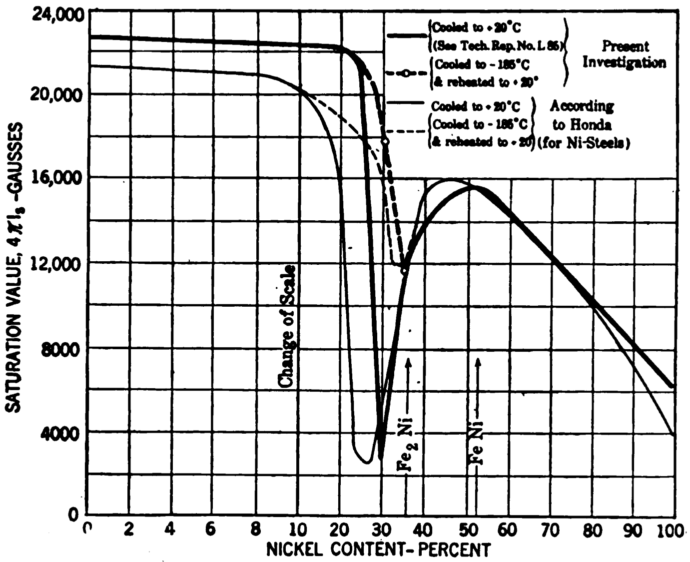

Fig. 17

The ordinates of this curve are in absolute degrees centigrade (= 273 = deg. cent.)

More recently Honda[15] has studied the magnetic

14. Circular No. 58. Invar and Related Nickel Steels April 4, 1916.

15. The Thermal and electrical properties of Nickel Steels *Sc. Reports* Tohoku Imp. Univ. 7, p. 59, 1918.

and electrical properties of nickel steels at ordinary temperatures and after quenching in liquid air. The latter treatment caused remarkable changes in the region of 25 to 30 per cent nickel, but no appreciable changes for other nickel contents, thus confirming the results already referred to. The results are shown in Figs. 17 and 18. On account of the foreign elements present in Honda's steels it seemed desirable to repeat his tests with pure alloys, and thus round out the investigation of the iron-nickel alloys covered in Part I.

Procedure. The samples used were selected from those used in the previous investigation, the prepara-

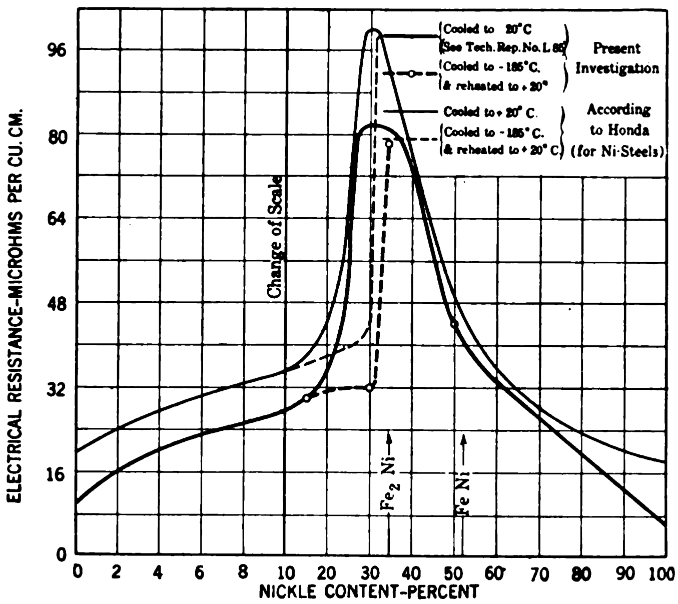

Fig. 18

tion of which is fully described in Part I. The test pieces used are as follows:

2 Ni 225—15 per cent Ni, 2 Rods 1.27 cm. (½ in.) diameter.
2 Ni 232—30 per cent Ni, 2 Rods as above and I ring 3.83 cm. (1½ in.) inside diam. and 4.47 cm. (1¾ in.) outside diam.
2 Ni 233—34.5 per cent Ni, 1 Rod and 1 Ring as above.
2 Ni 234—34.5 per cent Ni, 1 Rod and 1 Ring as above.
2 Ni 261—50 per cent Ni, 1 Rod and 1 Ring as above.
2 Ni 262—50 per cent Ni, 1 Rod and 1 Ring as above.

As a preliminary the rings were tested successively at room temperature, in CO_2 snow (– 70 deg. cent.), again at room temperature, then in liquid air (– 180 deg. cent.) and finally at room temperature. Then the rods were tested at room temperature, after having been cooled to – 70 deg., and after having been cooled to – 180 deg. The cooling to – 70 deg. was done by immersing the test pieces in gasoline, gradually adding CO_2 snow until no more would melt and maintaining the temperature for about half an hour by adding more snow from time to time.

Results. The results are tabulated in Table IV and shown graphically in Figs. 16, 17 and 18. It will be noted that while there is practically no change in the properties of the 15, 34.5 and 50 per cent alloys the 30 per cent alloy has undergone a marked change. Its saturation value, $4 \pi I_s$, was increased from 2700 to

Fig. 19—2 Ni 232 30 Per Cent Ni Cooled to Room Temperature. (100 Diameters)

14,600 by cooling to – 70 deg. and to 17,800 by cooling to – 180 deg. Similarly, the electrical resistance was decreased from 82 to 38 and to 32 by the above treatments. It is probable that the change would have gone to completion at – 70 deg. if the

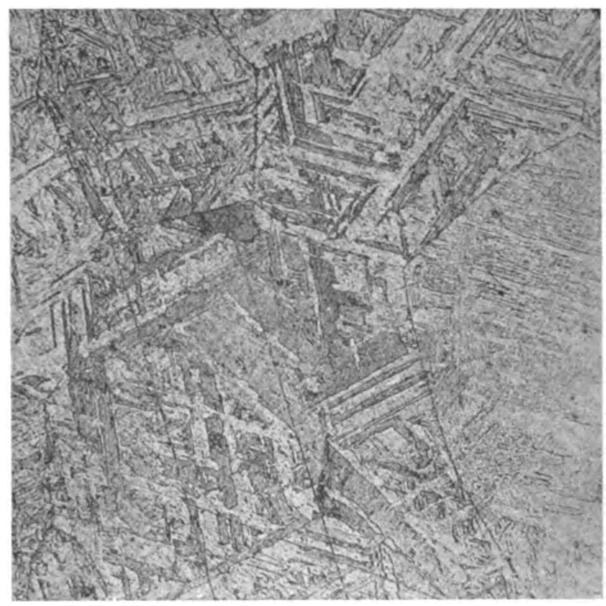

Fig. 20—2 Ni 232 30 per cent Ni Cooled to —70 deg. cent. and Reheated to Room Temperature. (100 Diameters)

testpiece had been held there sufficiently long and that the irreversible transformation point therefore lies between O and – 70 deg. thus confirming Dumas' results.

While only a few points were determined, they are sufficient to demonstrate that the cusp of both curves, after the completion of the transformations, occurs for approximately 34.5 per cent nickel instead of for 30 per cent as the previous investigation would lead one to believe. This points strongly towards the existance of the compound Fe_2Ni, corresponding to 34.6 per cent nickel, suggested by earlier investigators. The existence of the compound FeNi corresponding to 51.5 per cent nickel, is more doubtful, because there is no definite indication of it in the electrical resistance curve.

It is interesting to note that while the saturation value of the 30 per cent alloy was increased to a remarkable extent by being cooled to below the irreversible transformation point, the permeability at low flux densities was decreased and the hysteresis loss enormously increased, the latter 15 times. In other words, the reversible transformation produces a material with low hysteresis loss and low magnetic saturation, while the irreversible transformation produces a material with 6 times the saturation value, but with 15 times the hysteresis loss. Thermal and magnetic hysteresis thus go together.

It is also interesting to note that there apparently is no change in the microstructure of the 30 per cent alloy accompanying the marked magnetic and electrical transformation. Fig. 19 shows the microstructure of the alloy cooled to room temperature, and Fig. 20 after cooled to -70 deg. cent. and reheated to room temperature. The latter corresponds to magnetic and electrical properties widely different from those of the former, and yet the microstructures at 100 diameters are identical as far as can be seen. It is therefore apparent that the magnetic and electrical transformations are atomic or ionic in their nature.

The Fixation of Atmospheric Nitrogen by the Silent Electric Discharge Process–I

This paper is the the first of a series on the same type.

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AND
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THE very great increase in the demand for nitrates during the war for the manufacture of explosives and fertilizers, together with the shortage of imported Chile saltpeter, which was the principal source of nitrates before the war, has been emphasized sufficiently in previous papers. This condition of increased demand and curtailed supply led not only to the establishment of many manufacturing plants for the production of nitrates by well-known methods, but also to laboratory research and commercial development in connection with promising new processes.

Such a process, for obtaining nitric acid from the air by means of the silent electric or corona discharge at high voltage, has been investigated throughout a period of several years at Purdue University under the auspices of the Engineering Experiment Station of that institution. Improvements in the yield, resulting from a given input of electrical energy, are being made quite frequently as the investigation progresses and many of the peculiarities of both electrical and chemical reactions of the oxides of nitrogen, combined with ozone, are being disclosed as phenomena incidental to the process under consideration. It has, nevertheless, been considered advisable to present, as a progress report, the results obtained thus far in order that, in the spirit of co-operative research, discussions and suggestions of value will result which in turn will hasten the development of the process. With this object in view, the results of the investigation being carried on at Purdue University are presented in this paper.

It is well to point out at first the distinction between the process herein described and the arc method of nitrogen fixation. In the former, air is passed through an electro-static field of such intensity that marked corona and some static sparks are produced, but no power arc is established and the temperature is increased but slightly above that of the incoming air. While the arc process of nitrogen fixation is dependent principally upon the very high temperature of the power arc, the silent discharge reaction is the result of electrical ionization of the air at a relatively low temperature.

The fact that electro-static brush discharges and sparks will produce, in a confined volume of air, various oxides of nitrogen and ozone, has been known for many years. Oxidation of these lower oxides of nitrogen by an excess of ozone results in nitrogen pentoxide, N_2O_5. This gas, when absorbed in water, produces nitric acid from which the desired nitrates may readily be formed.

To be presented at the Boston meeting of the A. I. E. E., April 9, 1920.

Earlier Investigations

The investigation, to which this paper forms an introduction, was the result of the translation from the German, by Messrs. G. N. Unger, G. W. Payne and F. S. Weimer, of an article entitled, "The Formation of Nitric Oxides by the Silent Electric Discharge in a Siemen's Tube." The latter was submitted by Hugo Spiel for a doctor's degree at The Technical High School, Vienna, in 1909. Spiel gives credit for the first publication of the effect of this silent electric discharge upon air as follows:

> The first observations of the silent electric discharge in literature appeared about 1870, following the work of Andrew, Hauzau, Jean, Thenard and Boillit, with ozone and nitric acid. It concerned the decomposition of carbonic acid and turned the general interest to the chemical effect of the electric discharge in gases. In 1873 the French physicist, Moncel, published a work entitled, "Concerning the Condensed Discharge of the Induction Coil," in which he claimed to have discovered the above phenomena in 1853.

Following a review of the previous work done by others upon the problem, Spiel described a series of laboratory research investigations performed by him upon fixed volumes of air and various artificial nitrogen-oxygen mixtures. Spiel's apparatus consisted of a small glass or quartz Siemen's tube, using acidified water electrodes upon either side of an annular air space of only 3 mm. thickness. The electro-static discharge, within this space, was produced by an induction coil and condenser having a sparking distance of 40 cm., and a frequency of approximately 40 cycles per second.

As a result of the exposure of a confined volume of air to the electro-static discharge, at different pressures and voltages, Spiel noted during a single test; first, a decrease in pressure and later, at the minimum pressure, a reversal of the reaction. This reversal was indicated by the presence of brown fumes of NO_2. If the electric discharge was continued beyond this point, the pressure increased to the initial, or to a greater pressure, when equilibrium was established.

The conclusions reached by Spiel have been summarized in the appendix of this paper, because of the bearing they have upon this investigation and the inaccessibility of the original article.

Early Investigations at Purdue University

In planning a further investigation of this process,[1] it was decided that although the work must necessarily be performed with laboratory apparatus upon a comparatively small scale, when contrasted with commercial arc plants, the equipment should be designed and constructed in such a way as to provide for a continuous flow of air through the electric field. There is no reason apparent, therefore, to prevent the construction and continuous operation of a commercial plant based upon the same principle.

To produce the so-called "silent electric discharge" in a column of air, it is, of course, necessary to apply an electric potential between conducting plates or concentric pipes, Fig. 1, sufficient in magnitude to exceed the dielectric strength of air under the particular pressure at which such air is being forced through the apparatus, *i. e.*, the potential gradient must be such that the molecules of the air are torn apart into ions and neutral atoms which may reunite in new combinations. Such ionized air is a comparatively good conductor of electricity and unless special precautions are taken in the design of the tube, a power arc will result at one point and the potential will be lowered at other points in the field, thus eliminating the reaction.

Original Apparatus. The apparatus used in this first investigation is illustrated in Fig. 2. Following

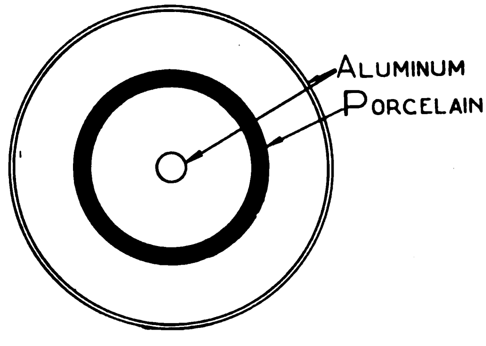

Fig. 1—Elevation of Corona Chamber

the passage of the air from the compressor on the left through air chamber, meter and drying apparatus in sequence, it passes into the discharge tube. This consists of a vertical aluminum tube 37.8 in. (96 cm.) in length and 2.91 in. (7.4 cm.) internal diameter, inside of which was mounted concentrically a glass tube of slightly greater length, 2.5 in. (6.35 cm.) diameter and 0.125 in. (0.318 cm.) thickness. This glass tube provides the barrier of higher dielectric strength than air to prevent the arc from forming. The potential is applied between a coaxial aluminum rod of 0.625 in. (1.59 cm.) diameter and the outer aluminum tube. The air passes upward between the glass and aluminum tube, and thence the gases pass downward between the central rod and the glass tube, emerging from the bottom into the mixing chamber. Receptacles are provided at the right with glass beads and distilled water or a solution of $N/10$ potassium hydroxide (KOH) for the fine subdivision and absorption of the gases. Traps are placed upon either side of the drying bottles to prevent the sulphuric acid, (H_2SO_4) which is used as the drying agent, from being carried into the meter or discharge tube. A similar trap is located between the mixing chamber and absorption apparatus to prevent the absorption water from being forced back into the mixing chamber.

1. Thesis entitled "The Fixation of Atmospheric Nitrogen by the Silent Electric Discharge at High Voltage," 1917 by G.W. Payne, G. N. Unger and F. S. Weimer.

Manometers and thermometers are installed, as indicated in the figure, for the purpose of determining pressures and temperatures of entering air and effluent gases, respectively.

Power Measurement. A potential in the neighborhood of 30 kilovolts, alternating at a frequency of 60 cycles, was furnished by a 200-kilovolt, 50-kv-a., air-cooled transformer. The tertiary coil of this transformer, whose potential was calibrated against the A. I. E. E. standard sphere gap in the secondary circuit, provided a convenient means of reading voltage. The potential terminals of the wattmeter were also connected to the tertiary coil. An ammeter and the current coil of a wattmeter were connected, as indicated in the figure, between the neutral point of the transformer winding and ground. Only one side of the transformer was used to supply the potential to the

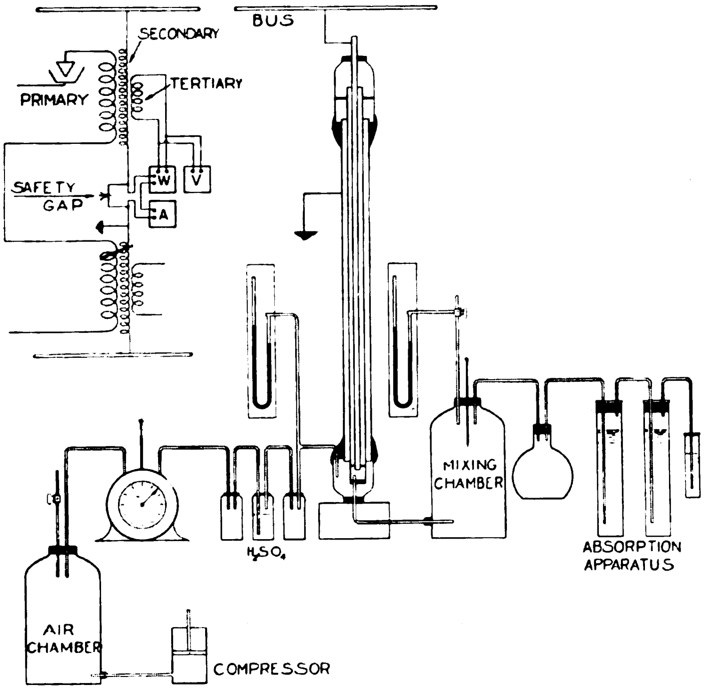

Fig. 2—Original Apparatus

discharge tube. Protective film cut-outs, connected around the meters, prevented accident in case the ground wires of the meters or tube should become disconnected. A Rowland dynamometer, calibrated over a wide range of power factor as a wattmeter, was used in these early tests for measuring the power input to the discharge tube. The difference between the readings of this dynamometer, with and without the tube connection, provided a measure of the net power supplied to the tube, quite apart from any transformer or corona losses on connecting bus bars. This method of power measurement is the same as that used in determining corona loss on transmission lines previously reported to the Institute.[2]

2. "Corona Losses between Wires at High Voltages," C. Francis Harding, Transactions A. I. E. E. Vol. XXXI (1912), page 1035.

With the methods of gas absorption and power measurement outlined, it was a comparatively simple matter to titrate the nitric acid formed or determine the amount of alkali neutralized thereby per kw-hr. of energy expended.

Conclusions of Original Investigation. The results of three (3) tests by Messrs. Unger, Payne, and Weimer are listed in Table I.

TABLE I.

NITRIC ACID YIELDS.

Test	Grams HNO_3 per kw-hour.
No. 1	4.17
2	2.55
3	5.55

A study of Table I indicates that thus far the yield by the silent discharge method is very much smaller than those of the arc processes. Some of the conclusions derived from the investigation as indicated seemed however, to warrant further research along similar lines.

1. The reaction is not necessarily a thermal one, but nitrogen pentoxide (N_2O_5) is formed at low temperatures by the action of the corona at high voltages.
2. Although this reaction is accompanied by much free ozone (O_3), the lower oxides of nitrogen, so objectionable in the arc process, are apparently not present to any great extent, except in case of reversal of the reaction.
3. Since the effluent gases consist principally of a mixture of nitrogen pentoxide (N_2O_5), ozone (O_3) and air, the absorption is more readily accomplished than with the arc process.
4. The gases emerge at comparatively low temperatures. Little energy is therefore carried away in the form of heat and no apparatus is needed to make efficient use of this heat energy.
5. The process is a continuous one and, as such, is more adaptable to commercialization than previous investigations of the silent discharge process which have been limited to a single confined volume of air.

Improved Apparatus

Encouraged by the possibilities of this process, in spite of the relatively low yields available thus far, the work was taken over upon a larger scale by the Engineering Experiment Station with the assistance of Messrs. H. W. Asire, S. S. Green and H. C. Thuerk.[3]

Apparatus operating upon the same principle, but much larger and more commercial in design, was constructed as indicated in Fig. 3.

3. Thesis entitled "The Fixation of Atmospheric Nitrogen by the Silent Electric Discharge Method," 1918 by H. C. Thuerk and S. S. Green.

The corona discharge takes place inside an aluminum tube five feet (1.52 m.) long and six inches (15.2 cm.) in diameter, mounted in a vertical position, the lower end being about 18 inches (45.7 cm.) from the floor. A 5/8-inch (1.59-cm.) aluminum rod is placed on the axis of the tube and extends 18 inches (45.7 cm.) above the end of the tube. The lower end of the rod is screwed into the end of a ½-inch (1.27-cm.) bakelite tube 15 inches (38.1 cm.) in length. A perforated

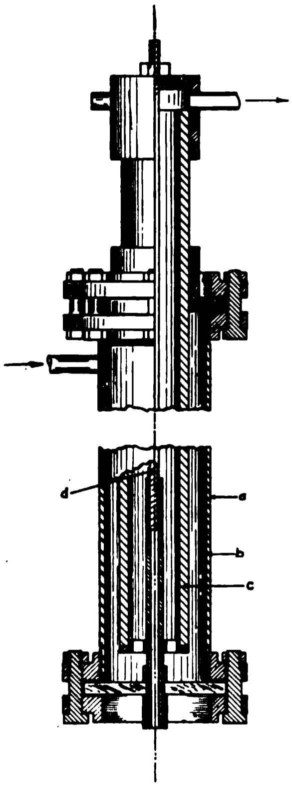

Fig. 3—Discharge Tube

a.—Wrought iron casing. c.—Porcelain dielectric.
b.—Aluminum lining. d.—Aluminum electrode.

bakelite disk, about four inches (10.2 cm.) in diameter, is arranged so that it may be screwed onto the outside of the bakelite tube. This disk furnishes the support for a glazed porcelain tube of three inches (7.62 cm.) inside diameter and ½ inch (1.27 cm.) thickness, the upper end of which projects beyond the end of the aluminum tube, but not as high as the aluminum rod. The top of the tube is closed with a bakelite cap placed over the end of the porcelain tube. A collar, also of bakelite, is inserted between the aluminum and the porcelain tubes. The joints between the porcelain and the bakelite are sealed with a rosin, beeswax and sealing wax compound, which is not appreciably affected by the gases. The bottom of the tube is sealed with a piece of thick plate glass, through the middle of which the bakelite tube is passed. By the use of a mirror, placed on the floor at the proper angle, a view of the inside of the tube is afforded.

Surrounding the aluminum tube is a length of wrought iron pipe, having flanges screwed on either end in such a way that the bakelite collar at the top and the plate glass at the bottom may be clamped securely.

In order that the temperature of the tube may be raised at will, a heating element, consisting of several hundred feet of iron wire, is provided. The heating element, wrought iron pipe and flanges are covered with a magnesia covering which decreases the radiation.

Air enters the tube near the top, and passes downward between the aluminum and porcelain tubes, through the holes in the bakelite disk and up through the inside of the porcelain tube, exhausting through a bakelite tube screwed into the cap over the end of the porcelain. The path of the air is shown in Fig. 4.

A mercury manometer, connected to the inlet pipe, indicates the relative pressure in the discharge tube. The temperatures of the incoming and outgoing gases are measured by alcohol thermometers whose bulbs are in actual contact with the gases. Mercury thermometers were not used on account of the breaking up of

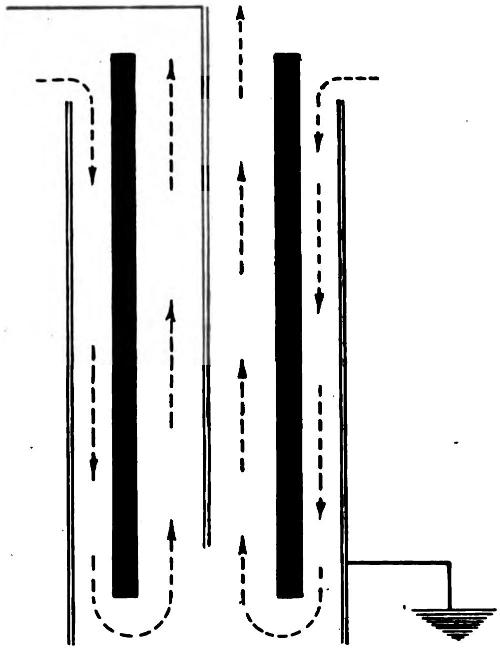

Fig. 4—Path of Air in Discharge Tube

the mercury column due to the static charges formed. The mercury is also a conductor which is, of course, a serious disadvantage, and makes their use unsatisfactory.

The aluminum rod is connected to the high-tension transformer, while the outer iron casing is grounded. With the proper voltage impressed on the discharge tube, the space both inside and outside of the porcelain tube may be filled with corona discharge.

Absorption Apparatus. The absorption apparatus consists of an absorbing chamber, separator and precipitator. This apparatus will be more easily understood by reference to Fig. 5.

The gases, leaving the discharge tube, bubble through a solution of sodium hydroxide (NaOH) of known strength, contained in the absorption chamber. The

bubbles of gas are made to come into contact with quite a large wetted surface as the chamber is partially filled with very short lengths of small glass tubing. The use of the tubing makes possible relatively high air velocities with but little back pressure. The absorbing liquid is titrated both before and after the run, in order to ascertain the amount of HNO_3 absorbed.

At certain air velocities, a fog is formed over the absorbing liquid and, in order to recover the acid carried with it, a separator, Fig. 5, working on the principle of the steam separator, is connected in series with the absorption chamber. In this separator the gas is forced to turn through an angle of 180 deg., while moving at a high velocity with the result that the heavier particles are thrown down, and collected in the bottom of the chamber.

From the separator, the gases pass to the precipitator, Fig. 5, in order that the finer particles of fog may be collected. This device is patterned after that of Cotrell. A glass tube, about 1½ inches (3.81 cm.) in diameter and 23 inches (58.4 cm.) in length, is coated with tinfoil up to within about six inches (15.2 cm.) of either end. The air passes in and out through the two side outlets blown in the glass near either end. A small (1/16-inch (1.59-mm.) diameter) aluminum wire, threaded throughout its entire length, is sealed into two small glass tubes about four inches (10.2 cm.) in length, which in turn are sealed into either end of the precipitator tube. Thus, quite a long creepage distance is secured, which is necessary when the surfaces become wet with nitric acid. This tube is operated with an induction coil giving a one-half inch (1.27 cm.) spark between needle points.

With the induction coil connected to the precipitator in such a way that the larger lobe of the wave is impressed on the threaded wire, the tube seems to work well. The smaller lobe is more or less excluded by point plate action.

Air Control. A small piston air pump is connected to a system of valves, in such a way that the discharge tube may be operated under pressures above or below the atmosphere, by a simple manipulation of the valves. The valves are provided with a pointer and dial, so that settings may be duplicated at any time. The fluctuations due to the pump are smoothed out by the use of an air tank, whether the system is working under pressure or vacuum. The air pump is driven by a d-c. motor, arranged with armature control of the speed. A voltmeter is connected across the armature circuit to act as an indicator of the motor speed.

Air leaving the pump bubbles through sulphuric acid, contained in two chambers in series, and then passes on through a tube containing soda lime. By

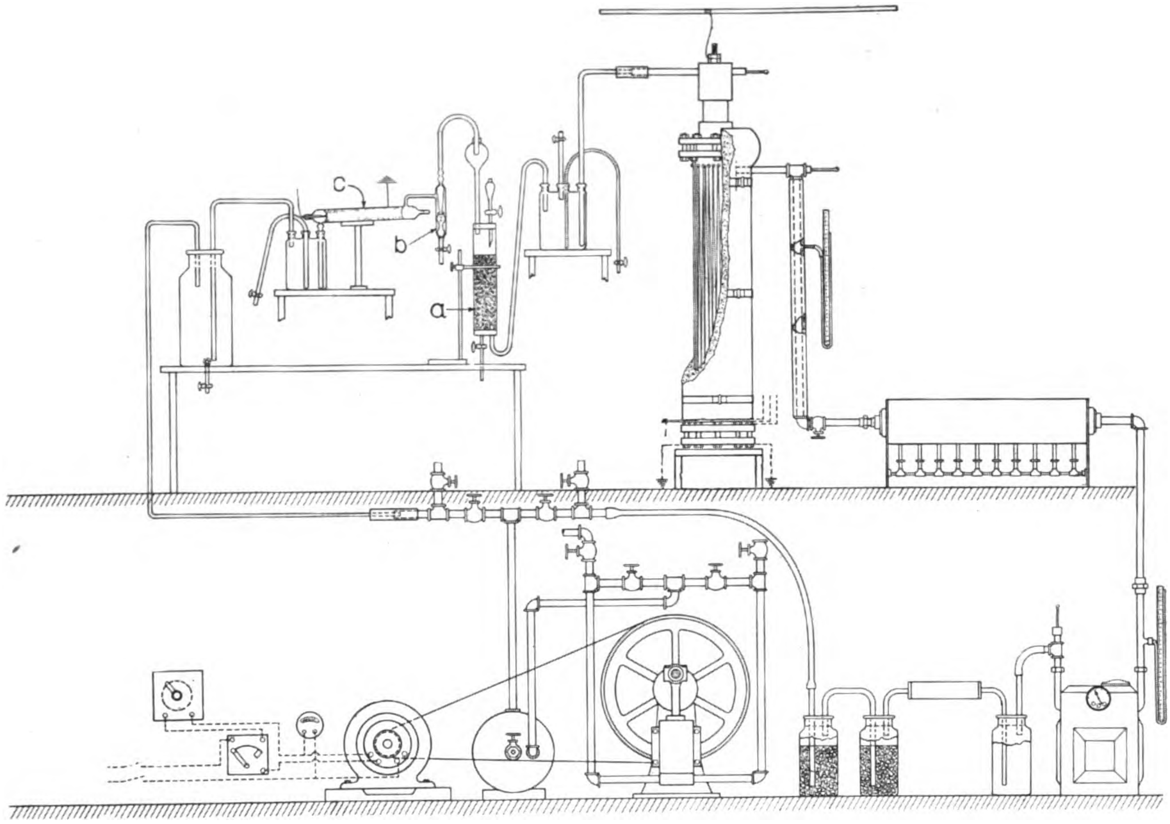

Fig. 5—Improved Apparatus
a.—Absorption chamber. b.—Separator.
c—Precipitator.

this process the air is rendered practically free from moisture and carbon dioxide CO_2.

A special gas meter, having a capacity of 100 cu. ft.,

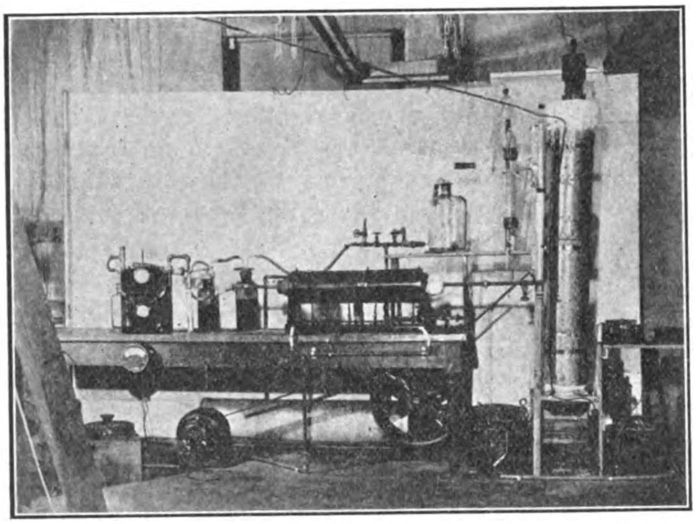

Fig. 6—Experimental Apparatus

(28.32 liters) is connected to a settling chamber through which the air passes after leaving the soda lime chamber. By use of the large dial with which the meter is pro-

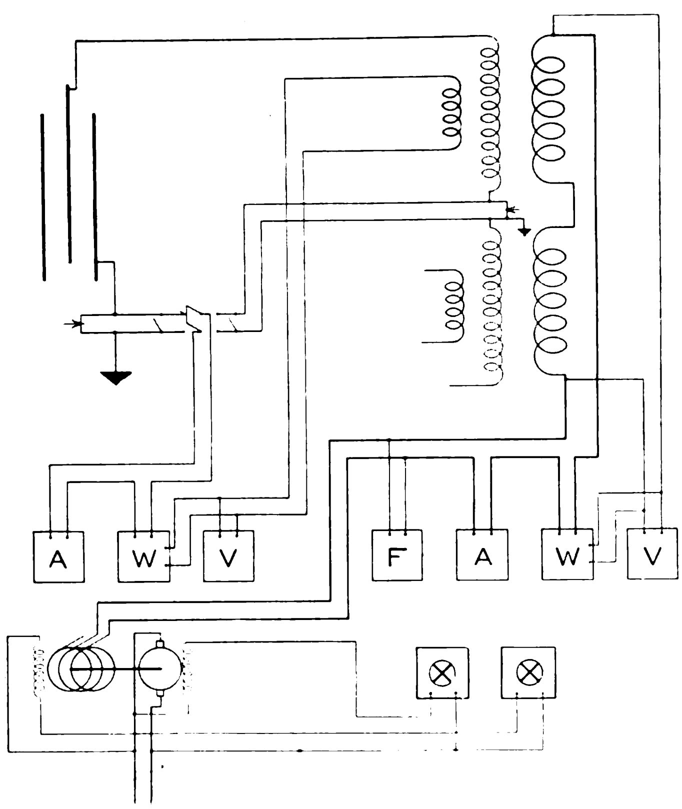

Fig. 7—Diagram of Connections

vided, readings are possible to one one-hundredth (0.01) of a cu. ft. (0.283 liter). The temperature and pressure of the air at the air meter are measured because the air meter is not capable of withstanding all of the pressures used in the discharge tube.

Upon leaving the air meter, the air passes through an air heater, where its temperature may be raised as much as required. This heater consists of a long tube, heated by ten gas burners, properly insulated to prevent excessive radiation. In some of the earlier work, the heater was used in conjunction with the heating element on the discharge tube to hold a constant temperature. It was found however, after several trials, that small temperature changes did not seem to affect the yields materially, and as a result all of the tests recorded in this paper were made at room temperature.

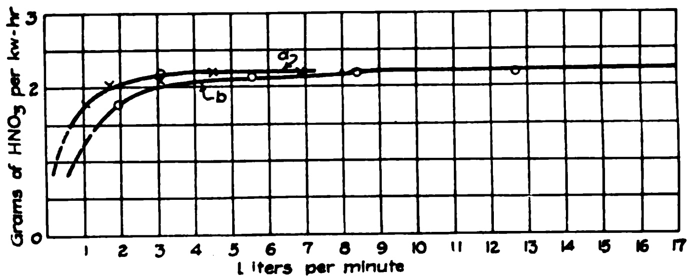

Fig. 8—460 mm.

a.—n. t. p. b.—actual.

This was of course held as nearly constant as possible. It is planned to make a set of runs in which the temperature will be made the independent variable. Upon leaving the gas heater the air passes through a valve, used for regulating the tube pressure, and then enters the discharge tube.

Power Measurement. The high tension winding of the transformer was grounded at its neutral point. The other terminals were connected to high-tension

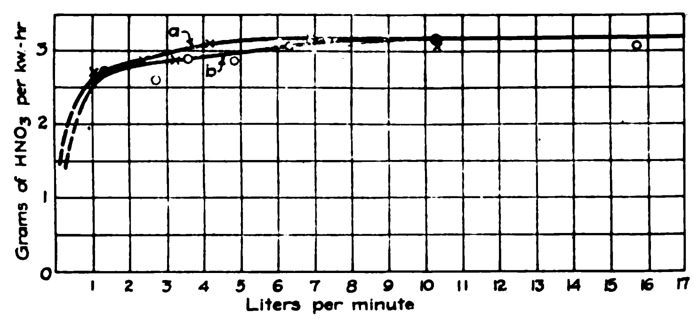

Fig. 9—560 mm.

a.—n. t. p. b.—actual.

buses. Each half of the secondary may be operated up to 100 kv. The excitation for the transformer is furnished by an alternator which gives practically a sine wave.

A test table has been arranged, equipped with various meters and rheostats. On this table, switching arrangements, Fig. 7, are provided so that the current in either circuit, *i. e.* from transformer to ground or, from discharge tube to ground, may be read on the same milliammeter. These currents differ because of the capacity of the transformer coils to ground, and also because of the actual electrostatic leakage occurring in the transformer.

A special low-reading wattmeter, whose potential coil is connected to the tertiary coil on the transformer, has its current coil in series with the milliammeter in order that readings of watts in tube circuit and transformer circuit may be taken independently. There is some considerable variation in the readings of the wattmeter in the two circuits with varying pressure in the discharge tube. This variation in wattmeter readings appears to be a function of the static sparks in the tube, and is greater than can be accounted for by capacity effects alone. This matter will be the subject of future investigation.

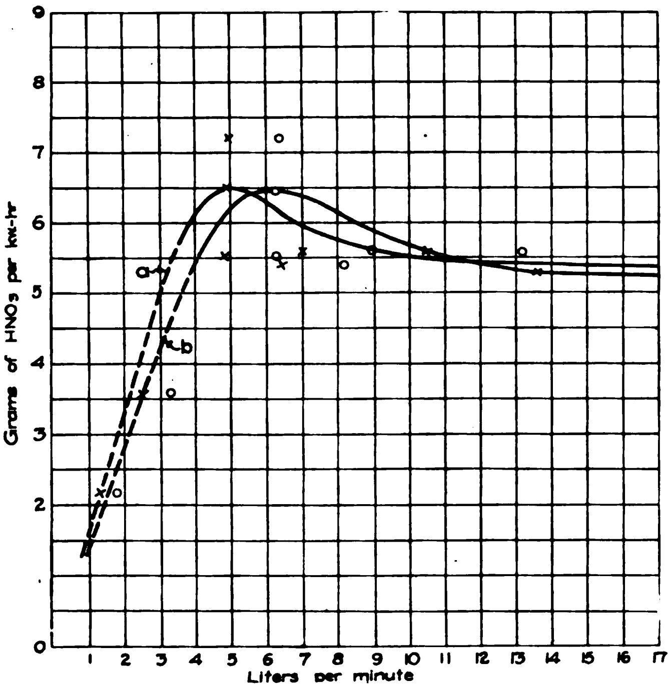

FIG. 660 MM.
a.—n. t. p. b.—actual.

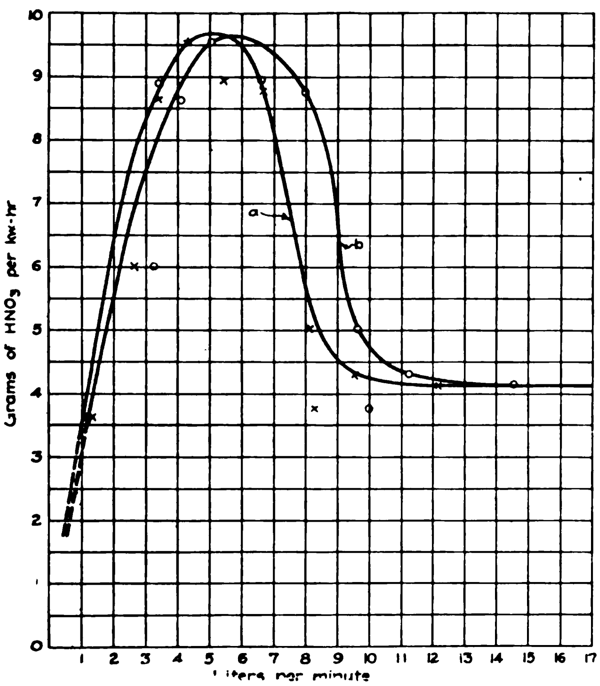

FIG. 11—710 MM.
a.—n. t. p. b.—actual.

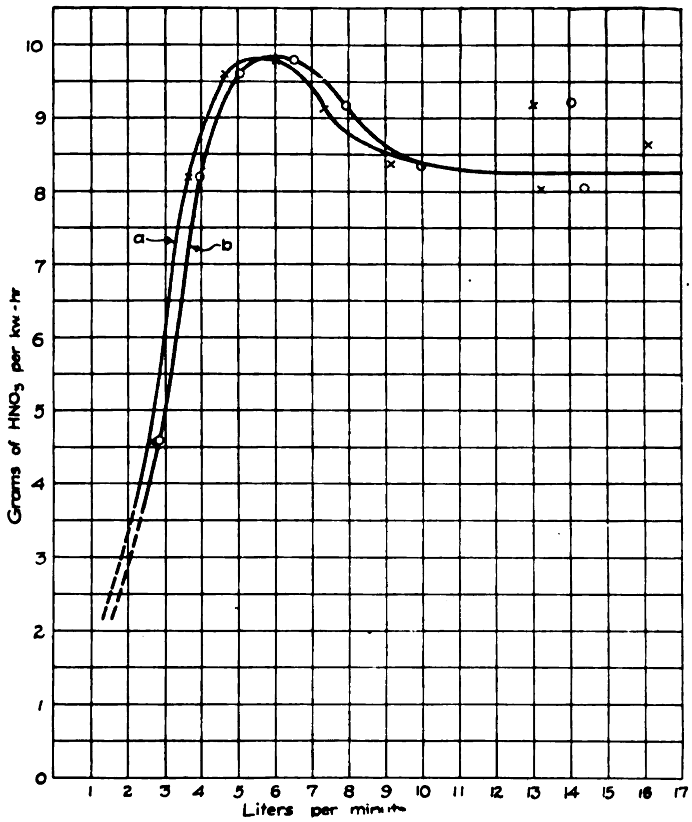

FIG. 12—780 MM.
a.—n. t. p. b.—actual.

Meters were connected in the primary circuit of the transformer for measuring the input power. The net power measured from the primary side has checked

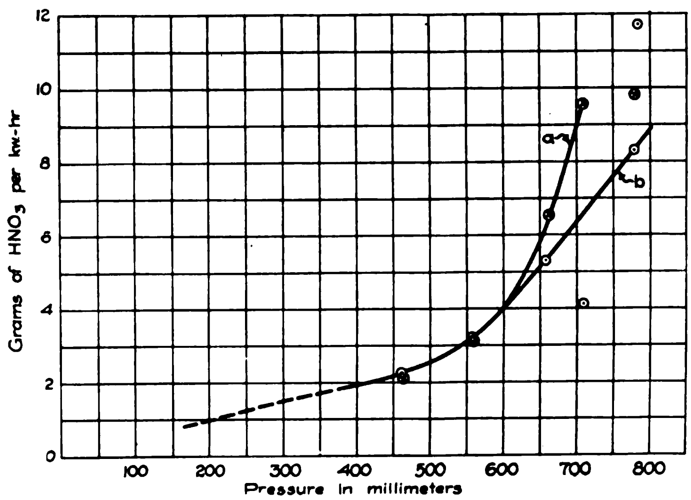

FIG. 13—PRESSURE YIELD CURVES
Constant Air Velocity (n. t. p.).

that observed on the secondary side within 10 per cent in practically every run made.

Results of Tests. A series of runs at pressures of 460, 560, 660, 710, and 780 mm. has been made. The power in the transformer circuit to ground was held

constant during all of these runs. The frequency was 60 cycles. Each run was 45 minutes in length. For each pressure a series of runs was made with air velocity as the variable. Figs. 8, 9, 10, 11, and 12 show the yield of HNO_3 per kilowatt-hour of energy

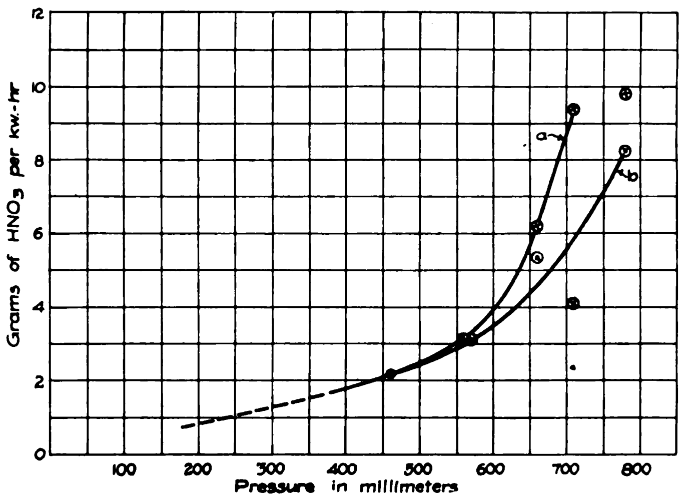

FIG. 14—PRESSURE YIELD CURVES
Constant Air Velocity (actual).

expended in the tube. The curves marked "Actual Velocity" refer to the actual velocity of a particle in passing through the discharge tube.

Figs. 13 and 14 show the relation between pressure and yield with constant air velocity. From these

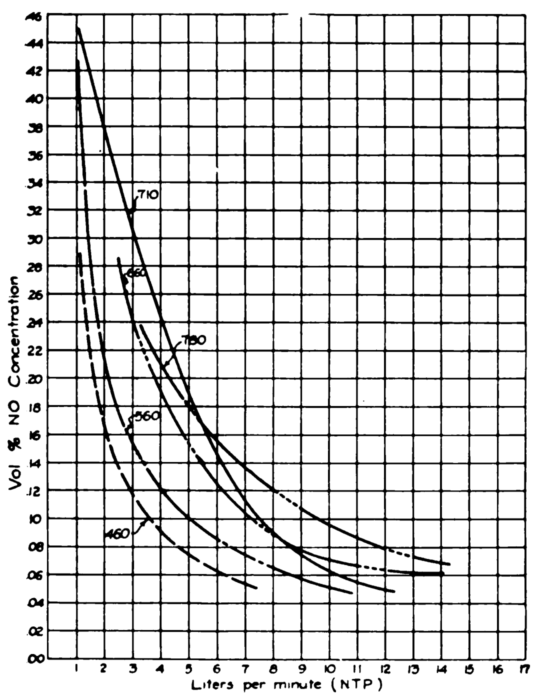

FIG. 15

curves it may be seen that the yield at the lower velocities is limited, but that at the higher velocities the limit has not yet been approached.

From the equations for the formation of nitric acid, it may be seen that the concentration of N_2O_5 will be half that of *N O* for any given value of nitric acid.

$$2NO + O_3 = N_2O_5$$
$$N_2O_5 + H_2O = 2HNO_3$$

The N O first formed is oxidized to N_2O_5 by the excess of ozone present so the N_2O_5 may be contrasted with 2 N O for the same yield of nitric acid.

The relation between per cent concentration of fixed nitrogen, calculated as N O, velocity and pressure is given in Figs. 15 and 16. These curves show that high concentration is to be secured at low velocity, but as seen in Figs. 13 and 14 at the expense of energy input. The concentration curves are therefore somewhat misleading from a commercial standpoint.

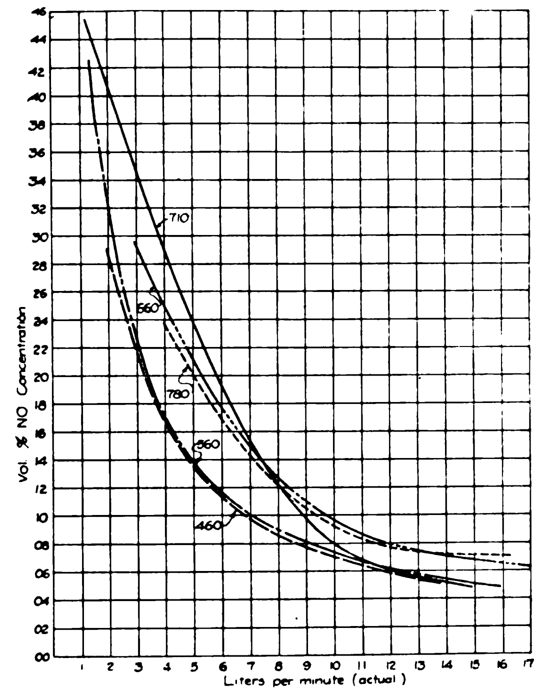

FIG. 16

It seems probable that all of the velocity-yield runs for the different pressures should follow the same general form. At low pressures the amount of gas to be dissolved was low and the efficiency of absorption higher. At the higher pressures, with more gas to take up, it is likely that the absorption was incomplete, especially at high velocities. Data taken recently have shown this to be the true condition.

From Fig. 12 the highest yield is seen to be 9.8 grams HNO_3 per kilowatt-hour. This is more than double the average yield obtained with the original apparatus. (Table I). From the results of unfinished work it is apparent that this yield can be materially increased by using the improved methods of absorption which are now being worked out. The N O concentration for this velocity and pressure is 0.204 per cent.

One of the greatest complications of this problem is the number of variables to be controlled. The

large number of variables explains the apparent contradictions so often found in the literature of the silent discharge. It has taken considerable time and patience to acquire the ability to secure sufficiently constant conditions so that runs may be made which will check satisfactorily. Very great care has been necessary in making the various runs and taking the data, to eliminate as far as possible personal errors.

Considerable difficulty encountered in the early work was that of keeping the joints tight. The situation was complicated by the fact that rubber joints in contact with ozone are destroyed in a very few minutes.

A beeswax, sealing wax, and rosin compound, which has been referred to before, was developed for use in making joints and has given excellent results. The proportions by weight are: Sealing wax 3; beeswax 2; rosin 5. The joints are made in about the same manner as the plumber wipes a lead joint.

Incidental Phenomena.—Fog. At certain air pressures and velocities a white fog is formed over the surface of the absorption liquid. In the low pressure tests slight fog is formed, while at the higher velocities no fog appears. In many cases the fog is an initial condition disappearing after the first ten or fifteen minutes of operation. As the pressure is increased the fog becomes stronger and in general remains longer, until at 780 mm. pressure the fog, at a velocity of six liters per minute, is so dense that it is not possible to see through three inches of it. The fog is found to contain some nitric acid, its concentration being subject to considerable variation. The fog formation is being investigated further.

Meter and Pressure Variation.—At certain air velocities the readings of all the meters connected in the transformer and tube circuits and, to a lesser degree those in the primary circuit show a cyclic variation. At low pressures the effect is very slight, but with increasing pressure it becomes more pronounced. The greatest variation at each pressure occurs at an actual velocity of six liters per minute. At velocities above and below this, the indications rapidly become steady. With but one exception, these variations do not extend over a period of more than 40 minutes. In most cases they do not occur after the first 20 minutes of operation.

When the variations are most pronounced, the manometer connected to the discharge tube shows a disturbance corresponding to that of the electric meters. The frequency seems to be about two per second, although it is not by any means constant.

From the velocity yield curves given in Figs. 8, 9, 10, 11, and 12, it is to be noticed that the curves begin to flatten out at about the critical velocity of six liters per minute.

In the discharge tube, nitrogen pentoxide (N_2O_5) is being formed, while at the same time, if subjected to discharge for too long a period, it is again broken down. These two actions are therefore opposing one another and both are a function of time. This action may have some bearing on the observed variations.

Another effect which should be mentioned has been termed "Initial effect." During practically every run made, in order to hold the wattmeter deflection constant, the primary voltage had to be reduced as the run progressed. This average potential decrease during runs amounted to about 3 per cent. The tertiary coil voltage did not show as high a percentage variation and in some cases no change was noted. Most of the observed changes took place in the first fifteen minutes of operation.

Analysis of Losses. The energy consumption in the discharge tube may be divided into four parts.

1. Warming up the Material of the Tube. Using the weight of the iron and aluminum parts of the tube, and the specific heats of the metals, an expenditure of 14.14 watthours will be required per degree cent. temperature rise.

2. Loss in the Porcelain Dielectric. In order that some idea of the magnitude of the dielectric losses in the porcelain might be obtained, a series of heat runs on a regular discharge porcelain tube was made. The outside of the tube up to within about a foot (30.5 cm.) of either end was covered with tinfoil, the corona discharge from the tinfoil edges being prevented by pressboard collars sealed over them. A snug fitting metal tube three inches (7.6 cm.) in diameter was slipped inside the porcelain, its length being such that the dielectric field was not distorted by its ends. The tinfoil was grounded, the inner tube being connected to the high tension supply. Alcohol thermometers placed on the tube indicated the temperature of the tube. From curves taken during this test the power loss in the porcelain dielectric will be of the order of 10 watts, its exact value depending upon the value of the current flowing, in any particular case. From the observed temperatures of the discharge tube and effluent gases the temperature rise of the porcelain is greater than that which would be caused by its own dielectric loss. On account of this the energy calculated as being used in warming up the porcelain will exceed the value obtained by test.

3. Heat Carried away by Discharge Gases. The amount of heat carried away by the air is very small, being of the order of 0.20 watthour per 1000 liters of air per degree cent.

4. Energy used in the Chemical Reactions. Using the figures given by Berthelot[4] the amount of energy required for the formation of enough N_2O_5 to produce one gram of nitric acid is 95.4 calories, or 0.11 watthour. For the ozone 667 calories or 0.78 watthours are required.

Assuming that the wrought iron tube and the aluminum tube are at the same temperature, and that the

4. Smithsonian Physical Tables, 6th Edition.

porcelain tube is at the temperature of the discharge gases the following energy relations are secured, based upon their respective weights, specific heats and assumed temperatures.

Metal parts Average rise 5.6 deg. cent. loss	= 79.2 watthours
Porcelain tube Average rise 9.35 deg. cent. loss	= 27.1 watthours
Effluent gases 9.35 deg. rise—478 liters loss	= 0.9 watthour
Chemical reactions 2.13 grams HNO_3 (per hour)	= 0.24 watthour
0.96 grams ozone	= 0.78 watthour
	108.2

The power read on the wattmeter when connected in the tube circuit was 134 watts, leaving a difference of 25.8 watthours to be accounted for. Some of this may be due to temperatures existing inside the discharge tube higher than those used in the calculations. This error is not likely to be very large, however.

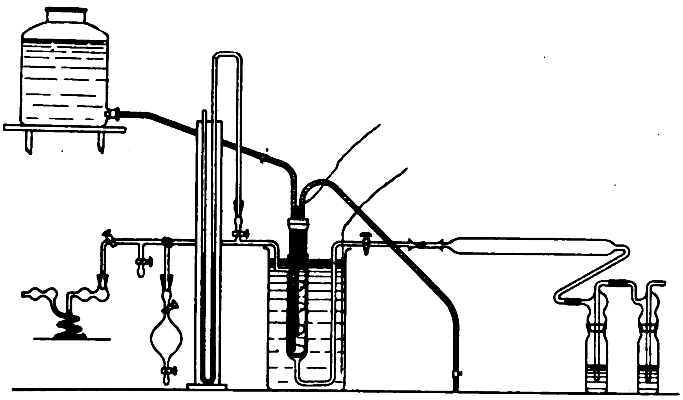

Fig. 17—Spiel's Apparatus

Conclusions. This work is but well begun, and no prediction can be made with any degree of certainty, yet the results obtained thus far are quite promising. Improved absorption apparatus has already indicated that increased yields may be expected. The process is very simple, and the first cost and maintenance of a plant would not be high. The difficulties of operation associated with the use of high temperatures are obviated.

Referring to Anderegg's calculations,[5] based upon his theory of the reaction, the ideal yield from the silent discharge process, if all the electrical energy were available for the reaction, would be 250 grams of nitric acid per kilowatt-hour. The theoretical possibilities from the thermal reaction, according to thermodynamical calculations, represent a yield of only 134 grams of acid per kilowatt-hour at a temperature of 4200 deg. cent. If the former process can be developed to the present efficiency of the arc process, the yield will be greater and the first cost and operating expenses will probably be much less because of the simpler apparatus involved.

5. "The Calculation of the Efficiency of the Silent Discharge Process for Nitrogen Fixation," F. O. Anderegg, Science, 50, 49 (1919) and Chemical Abstracts *13*, 3090 (1919).

In general, those reactions approximating most closely natural phenomena are found ultimately to be most satisfactory and economical. Nature provides dilute nitric acid for the fertilization of the soil by the ionization of the air as a result of electric discharges in the atmosphere. The gases thus produced are absorbed by the moisture of the clouds or rain and are distributed over the land. Such a process is identical in principle with that under discussion in this paper.

This work has been accomplished only by the generous cooperation of many interested investigators. Dr. F. O. Anderegg in particular, Assistant Professor of Chemistry at Purdue University, has followed the work in detail and has made many suggestions of value. The hearty appreciation of the authors is extended to him, to other collaborators mentioned in the paper, to Professor H. C. Peffer, Head of the School of Chemical Engineering, and Mr. Emerson Pugh, instructor in the School of Electrical Engineering. The departments of Chemistry and Physics have also rendered services which are hereby recognized with appreciation.

The Engineering Experiment Station at Purdue University will continue the investigation of the "Fixation of Atmospheric Nitrogen by the Silent Discharge Process."

APPENDIX

In Table I will be found a summary of the results of Spiel's experiments upon fixed volumes of air. The change of primary current of the induction coil indicated in the second column of the table, no doubt varied the voltage of the secondary and therefore the energy input to the Siemen's tube over a considerable range, but no record of such energy or the yields of nitric acid were reported.

TABLE I.
SUMMARY OF SPIEL'S RESULTS

No. of experiment.	Prim. current.	Pressure mm.	Temperature deg. cent.	Time reversal minutes	Time equilibrium minutes	N O concentration vol. per cent
1	1.9	715 –744	12 –15.3	120	175	0.7
2	1.9	716 –748.5	14 –14.2	110	..	4.4
3	1.9	481.5–503.5	14.3	39	51	0.6
4	1.9	481.5–502	15	43	..	5.6
5	1.9	345.5–353.5	16 –16.1	14	85	0.5
6	1.9	344 –352	15.5–15.7	11	..	6.6
7	3.0	729.5–746	17 –17.1	30	50	0.4
8	3.0	721.5–746.5	16.1–16.2	31	..	4.2
9	5.0	731 –760	14 –14.2	11	80	0.1
10	5.0	731 –750	14	11.5	..	3.6

The analyses were made after the equilibrium was reached for the experiments of odd number. In the even numbered experiments, the analyses were made as near the reversal point as possible.

Conclusions

The conclusions derived by Spiel as the result of his work on air are quoted as follows:

1. "With the discharge in enclosed volumes of air the final equilibrium concentration gives nitric oxide below one volume per cent for these conditions."

2. "Decrease of the original pressure essentially alters the equilibrium concentration."

3. "Increase in the primary current decreases the equilibrium concentration."

4. "The pressure decrease, which the gas undergoes, as is to be seen from curve, Fig. 17, varies between 8 and 34 mm. This pressure decrease depends not only upon the formation of ozone, but also upon the formation of oxides of nitrogen for, as can be seen from the red color of the gas at the time of reversal, and as has been proven by the determinations of concentration, much more oxidized nitrogen is present before and at the time of reversal, than at equilibrium."

This abrupt and strong reversal is a very peculiar phenomenon. It has been checked by Anderegg in the Chemical laboratory of Purdue University. The reversal has been shown by Spiel to be affected by changes of temperature. An investigation is being

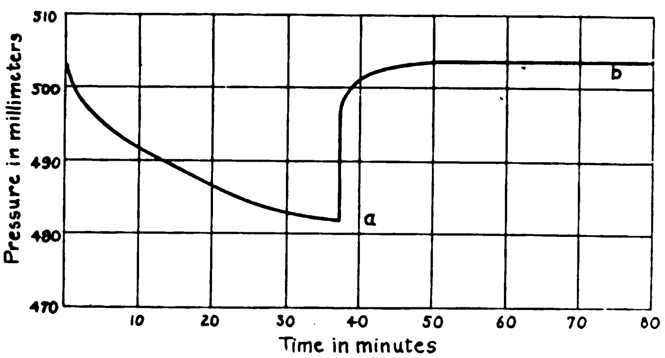

FIG. 18

a.—5.6 vol. per cent N O.
b.—0.6 vol. per cent N O.

undertaken by R. E. Nelson to see what effect the maintenance of a very constant temperature will have on the reversal.

5. "The concentration at the time of reversal in experiments at atmospheric pressure is about six times the final concentration. For lower pressures this ratio is raised, the final concentration being lowered; the reversal concentration increases rapidly. With 500 mm. pressure at the time of reversal about 10 times, with 350 mm. about 12 times as much NO is present as in the final equilibrium."

6. "With increased current, the reversal as well as the final concentration decreases considerably."

7. "The time after which reversal occurs varies between 12 and 110 minutes; the latter time, which was obtained with air at atmospheric pressure and 1.9 amperes, agrees with the results of Hantefeuille-Chappius."[6]

6. *Comptes rendus* 92 (80), 1881; 92 (134), 1882.

The conclusions reached by Spiel resulting from experiments with initial mixtures of air and various proportions of oxygen and nitrogen are to the effect that the concentration is increased and the time required to produce a reversal of the reaction is lowered by higher oxygen concentrations. He further decides the "The Silent Electric Discharge is not concerned with a thermal effect."

SPECIFICATIONS FOR STARTING AND LIGHTING BATTERIES FOR MILITARY TRUCK SERVICE

Special importance attaches to the formulation of satisfactory specifications for batteries intended for starting and lighting service, because of the magnitude of the industry at the present time and the fact that many new manufacturers are entering the field. The government desires adequate specifications to insure getting good batteries and it is believed that the government specifications, carefully drawn, will react to benefit the public who purchase these batteries in enormous quantities every year.

A conference was held at the Bureau of Standards on February 25th to consider a draft of specifications which has been prepared by this Bureau at the request of the Motor Transport Corps. These specifications, while intended for the Motor Transport Corps particularly, will probably receive wider acceptance in view of the fact that there appear to be no adequate specifications for starting and lighting batteries at the present time.

The conference was called, at the request of the Motor Transport Corps, by the Society of Automotive Engineers who invited members of the Electrical Equipment Committee of that society, representatives of the manufacturers, members of the American Institute of Electrical Engineers' Committee on Storage Batteries, representatives of the Navy Department, the Bureau of Standards, and the Motor Transport Corps.

The matters discussed included the capacity and arrangement of the batteries; the method of rating them; specifications for the construction, quality of materials, and the electrolyte. Tests of the battery were outlined to include measurements of the capacity, the retention of charge, the purity of the electrolyte, life tests and vibration tests. While the general form of the specifications was agreed upon, together with a satisfactory system of ratings, some details as to dimensions and performance were left for further consideration of sub-committees, and, consequently, it will be some time before the specifications will be ready for publication.

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with which is incorporated the PROCEEDINGS of the A. I. E. E.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

APRIL INSTITUTE MEETING IN BOSTON

On Friday April 9, 1920, the American Institute of Electrical Engineers will hold its 359th meeting at the Copley Plaza Hotel, Copley Square, Boston, Mass. This meeting will be held jointly with the American Electrochemical Society and will be under the auspices of the Boston Section and the Committee on Electrochemistry and Electrometallurgy. Arrangements have been made for the registration of Institute members in the lobby of the hotel at 9 a. m.

The first Institute session, held jointly with the A. E. S., will open in the Swiss Room on Friday at 9:30 a. m. for the reading and discussion of the papers of the symposium *Electrically Produced Alloys*. A trip to the Lynn works of the General Electric Company is scheduled for 1:30 p. m. At 6:30 p. m. a subscription dinner will be served in the Swiss Room, followed by the second technical session at which papers will be presented in the symposium *Power for Electrochemical Purposes.*

On Thursday, April 8th, the A. E. S. will hold sessions at the Copley Plaza, morning and afternoon; and on Saturday, April 11th, in the morning at Harvard University. On Thursday evening at 8:30 p. m. the A. E. S. has planned a Get-together Smoker at the Copley Plaza. Institute members are cordially invited to attend all of these functions.

PROGRAM

Friday, 9:30

SWISS ROOM, COPLEY PLAZA HOTEL.

Technical Session on "Electrically Produced Alloys."

A. I. E. E. PAPERS:

Electric and Magnetic Properties of Nickel-Iron Alloys, by T. D. Yensen.

Nitrogen Fixations by the Silent Discharge Method, by C. F. Harding and K. B. McEachron

A. E. S. PAPERS:

Properties of Ferro Silicon, by F. A. Raven

Ferro Manganese, by E. S. Bardwell.

Manufacture of High-Speed Steel in the Electric Furnace, by R. C. McKenna.

Ferro Cerium, by Alcan Hirsch.

Ferro Zirconium, by Theodore Swann.

Ferro Phosphorus, by B. G. Klugh.

Nichrome and Other Special Alloys, by R. M. Major.

Electrical Properties of Titanium Alloys, by M. A. Hunter.

1:30 p. m.

Inspection Trip to Lynn Works of the General Electric Co.

6:30 p. m.

Informal Subscription Dinner at the Copley Plaza Hotel.

8:30 p. m.

Technical Session on "Power for Electrochemical Industries."

A. I. E. E. PAPERS:

Power for Electrochemical Plants, by John M. Harper.

Automatic Control of Arc Furnace Electrodes, by John A. Seede.

Reactors for Electric Furnace Circuits, by H. A. Winne.

Economies of the Power Situation, by C. A. Winder.

A. E. S. PAPERS:

Electric Furnace Power from the Standpoint of the Central Station, by E. A. Wilcox.

The Electric Furnace and the Central Station, by H. L. Hess.

Location of a New England Electrochemical Plant, by C. T. Maynard.

Water Powers on the Pacific Coast, by F. F. Fowler.

Power Development in Scandinavia, by J. W. Beckman.

Power Problems from the Standpoint of the Furnace Operator, by W. G. Berlin.

Inspection Trip

On Friday afternoon there will be an inspection trip through the works of the General Electric Company at Lynn, Mass. This trip will be in charge of the General Electric Company, which has very kindly offered to supply transportation from in front of the hotel to the Lynn works and return. Trolley cars will leave promptly at 1:30 p. m. A printed description of the trip may be obtained at the registration desk on Friday morning.

Dinner

A subscription dinner will be served in the Swiss Room of the Copley Plaza Hotel at 6:30 p. m. Tickets should be obtained at the registration desk as early as possible in order that the dinner Committee may make arrangements for the required accommodations.

FUTURE A. I. E. E. MEETINGS

New York, May 21, 1920. Annual business meeting of the Institute, at which the annual report of the Board of Directors will be presented, and the report of the Tellers Committee announcing the officers elected for the coming year will be read. The Edison Medal will be presented to William LeRoy Emmet.

Annual Convention, June 29-July 2. The annual convention of the Institute will be held at the Greenbrier, White Sulphur Springs, West Virginia, June 29-July 2. President Townley has appointed the following Convention Committee:

Messrs. John H. Finney, Chairman
Walter A. Hall
F. L. Hutchinson
Farley Osgood
Charles Robbins
A. M. Schoen
W. I. Slichter

This committee will make all necessary arrangements for the Convention, with the exception of the technical sessions for which the Meetings and Papers Committee will provide.

Pacific Coast Convention, Portland, Ore., July 21-23. The 1920 Pacific Coast Convention will be held at Portland, Ore., July 21-23. Details will be announced later.

FUTURE SECTION MEETINGS

Cleveland.—April 20, 1920. Subject: "The Sperry Gyroscope." Speaker: Mr. Robert B. Lea, Sperry Gyroscope Company.

May 18, 1920. Subject: "Some Present Day Problems in Electrical Research." Speaker: Prof. V. Karapetoff, Cornell University.

A. I. E. E. DIRECTORS MEETING

MARCH 12, 1920

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Duquesne Club, Pittsburgh, on Friday, March 12, 1920, at 11:00 a. m.

There were present: President Calvert Townley, New York; Managers Charles S. Ruffner, Wm. A. Del Mar, L. F. Morehouse, New York, Charles Robbins, Wilfred Sykes, F. D. Newbury, Pittsburgh, E. H. Martindale, Cleveland, Walter A. Hall, West Lynn, Mass.; Secretary F. L. Hutchinson, New York.

A report was presented of a meeting of the Board of Examiners held March 8, 1920; and upon the recommendation of the Board the following action was taken upon pending applications: 73 Students were ordered enrolled; 227 applicants were elected to the grade of Associate; 15 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 14 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow.

The Secretary announced the following committee appointments made by the President since the last Board meeting: Annual Convention Committee—John H. Finney (Chairman), Walter A. Hall, F. L. Hutchinson, Farley Osgood, Charles Robbins, A. M. Schoen, W. I. Slichter; U. S. National Committee of the International Electrotechnical Commission—James Burke appointed a second Vice-President of the Committee, P. G. Agnew, Walter C. Fish, A. H. Moore, additional members; Board of Examiners—Professor J. H. Morecroft, to succeed Murray C. Beebe, resigned.

Upon the recommendation of the Chairman of the Sections Committee, a request for authority to organize an Institute Section at Providence, R. I., was granted.

Mr. L. T. Robinson was appointed as an alternate for Mr. H. M. Hobart as a representative of the Institute on the American Engineering Standards Committee during Mr. Hobart's absence in Europe as a delegate of the U. S. National Committee of the I. E. C. to a meeting in Brussels, March 27.

The Secretary announced that arrangements have been made for a Carnegie Memorial Service in the Engineering Societies Building, New York, on Sunday, April 25, at 4:00 p. m., several societies cooperating with the United Engineering Society.

Upon the recommendation of the Finance Committee, monthly bills amounting to $20,377.19 were approved.

In addition to these routine actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the Journal under suitable headings.

A. I. E. E. ANNUAL ELECTION

At the meeting of the Board of Directors of the Institute held in Pittsburgh, March 12, the report of the Tellers Committee giving the result of its canvass of the nomination ballots received for the offices to be filled at the coming annual election, was presented.

This report included the names of all candidates eligible for election, the names of those who received less than 3 per cent of the total nomination vote having been eliminated, in accordance with the requirements of the Constitution.

The Board resolved itself into a committee of the whole and an informal discussion followed, at the close of which the committee arose and reported its recommendations to the Board. The Board then selected a complete ticket of "Directors' Nominees" for the respective offices, in accordance with the provisions of the Constitution. This ticket is as follows:

For President:	A. W. Berresford, Milwaukee, Wis.
For Vice-Presidents:	C. S. Ruffner, New York, N. Y.
	E. H. Martindale, Cleveland, O.
	Charles Robbins, Pittsburgh, Pa.
	C. E. Magnusson, Seattle, Wash.
	C. S. McDowell, U. S. Navy
	L. T. Robinson, Schenectady, N. Y.
For Managers:	E. B. Craft, New York, N. Y.
	Harold B. Smith, Worcester, Mass.
	James F. Lincoln, Cleveland, O.
For Treasurer:	George A. Hamilton, Elizabeth, N. J.

The election ballots will be mailed to the entire membership prior to April 1.

A complete report of the Tellers Committee follows:

March 5, 1920

To the Board of Directors,
American Institute of Electrical Engineers.

Gentlemen:

This Committee has counted and canvassed, in accordance with Article VI of the Constitution, the nomination ballots received for officers of the Institute for 1920-1921. The result is as follows:

Total number of envelopes said to contain ballots, received from the Secretary		1049
Rejected on account of bearing no identifying name on outer envelope	13	
Rejected on account of having reached Secretary's office after Feb. 28	128	
Rejected on account of ballot carrying signature of voter	1	142
Leaving as valid ballots		907

These valid ballots were counted and the result is shown below:

FOR PRESIDENT

A. W. Berresford	324
C. E. Skinner	111
A. M. Schoen	61
William McClellan	38
N. A. Carle	38
J. B. Fisken	30
Scattering and blank	305
Total	907

(The scattering vote was divided among 69 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

FOR VICE-PRESIDENTS

C. S. Ruffner	711
E. H. Martindale	700
Charles Robbins	698
C. E. Magnusson	686
C. S. McDowell	142
L. T. Robinson	89
J. B. Whitehead	80
H. P. Liversidge	51
Robert Sibley	34
W. S. Lee	33
Philip Torchio	32
Scattering and blank	2186
Total	5442

(The scattering vote was divided among 272 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR MANAGERS

E. B. Craft	679
Harold B. Smith	665
James F. Lincoln	649
Scattering and blank	728
Total	2721

(The scattering vote was divided among 86 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR TREASURER

George A. Hamilton	687
Scattering and blank	220
Total	907

(The scattering vote was divided among 13 candidates, each of whom received less than 3 per cent of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

Respectfully submitted

EDW. J. K. MASON, *Chairman*
PHILANDER NORTON
CHAS. M. FULK
WILLIAM P. ABENDROTH
P. C. PAQUETTE
Committee of Tellers

A. I. E. E. MEETING IN PITTSBURGH

The 358th Meeting of the Institute was held at the William Penn Hotel, Pittsburgh, Pa., on March 12th, under the auspices jointly of the Pittsburgh Section and the Traction and Transportation Committee. The total attendance of members and guests was approximately 600.

The morning was devoted to an inspection trip through the works of the Westinghouse Electric & Mfg. Co. at East Pittsburgh, after which the visitors were entertained at luncheon by the company.

The afternoon technical session was called to order at 2:30 p. m. in the ballroom of the hotel. After opening remarks by President Townley congratulating the Institute on the progress made since its inception, on its largely increased membership, and the position it occupies in the field of electrical engineering, both nationally and internationally, J. G. Carroll, Chairman of the Pittsburgh Section presided. The papers of the afternoon session were then presented: "Short-Circuit Protection of D-C Substations" by J. J. Linebaugh, read by C. M. Davis; "Flashing of 60-Cycle Synchronous Converters and Some Suggested Remedies," by Marvin W. Smith; "Automatic Railway Substations," by Frank W. Peters; "Automatic Substations for Heavy City Service," by R. J. Wensley.

These papers were discussed by F. D. Newbury, S. Q. Hayes, C. H. Jones, D. C. Hershberger, C. A. Butcher, Donald Bowman, Frank W. Peters, J. F. Trittle and L. D. Bale. Closure by the authors, J. F. Trittle closing for J. J. Linebaugh.

A telegram was read from W. S. Murray, Chairman of the Traction and Transportation Committee regretting his absence.

The informal dinner which was served at the hotel at 6:15 p. m. was attended by over 300 of the members and guests. At the dinner, S. M. Kintner acted as chairman and brief addresses were made by E. H. Sniffin, Manager of the Power Department of the Westinghouse Elec. & Mfg. Co., A. W. Thompson, President of the Duquesne Light Co. and Pittsburgh Railways Co., and President Townley. J. G. Carroll, Chairman of the Pittsburgh Section, thanked the company for their attendance.

At the evening session two papers were presented on "The Two Designs for the Chicago, Milwaukee and St. Paul Locomotives," by A. F. Batchelder and S. T. Dodd, (read by Mr. Dodd) and N. W. Storer. These papers were discussed by S. Q. Hayes, R. L. Wilson, R. J. Wensley, E. H. Martindale, F. D. Hall, R. E. Ferris, A. M. Candy, L. J. Hibbard, Calvert Townley and C. M. Davis, with closure by S. T. Dodd and N. W. Storer.

SPRING MEETING OF ENGINEERING SECTION, NATIONAL SAFETY COUNCIL

The Engineering Section of the National Safety Council will hold a spring meeting in the Engineering Societies Building, New York, on Tuesday, April 27, ending with a dinner at the Commodore Hotel. The program includes the following subjects:

The Relation of Safety to Engineering Efficiency.
Safety Education in Engineering Colleges.
Safety Standards.
The Engineer's Place in the Modern Industrial World.

The list of speakers will include engineers of prominence in the engineering world as well as in the safety movement.

To bring the safety movement into closer touch with the engineering societies and the engineering profession in general is the principal purpose of the meeting. A cordial invitation is extended to all members of the A. I. E. E. to attend the morning and afternoon sessions, and particularly the dinner at the Commodore Hotel.

JOHN FRITZ MEDAL AWARDED TO ORVILLE WRIGHT

The John Fritz Medal Board of Award, composed of representatives of the national societies of Civil, Mining, Mechanical and Electrical Engineers, met on January 16, 1920, and awarded the medal for 1920 to Mr. Orville Wright "Fro achievement in the development of the airplane."

The presentation will take place Friday May 7, at 8:30 p. m. in the Engineering Societies Building, 33 West 39th St., New York. The principal speakers will be Maj. Gen. George O. Squire, Chief Signal Officer, and Col. Edward A. Deeds of Dayton, Ohio. Presentation will be made by Mr. Ambrose Swasey, Mr. D. B. Thayer, Chairman of the Board of Award, presiding.

The medal has been awarded in earlier years to:

Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas A. Edison, Charles T. Porter, Alfred Noble, Sir William Henry White, Robert Woolston Hunt, John E. Sweet, James Douglas, Elihu Thomson, Henry Marion Howe, J. Waldo Smith, George W. Goethals.

STUDENT BRANCH OF A. I. E. E. AT UNIVERSITY OF PENNSYLVANIA

With the recent formation of the student branch of the American Institute of Electrical Engineers at the University o fPennsylvania, Philadelphia, a plan has been developed to stimulate interest in the activities of the branch and to include in these activities all the students in the Electrical Engineering Department of the University.

The Seminar hour, formerly attended only by Senior students has been modified to include Freshmen, Sophomore and Junior as well as the Senior students. These Seminar hours are part of the required curriculum, and are, at the same time, regular technical sessions of the Institute student branch, being presided over by the Chairman of the branch, although the preparatory work on papers is under the direct supervision of the instructing staff.

Occasional evening meetings of the student branch are held which are of a social nature in distinction to the technical sessions. By this general plan, the interest in the Seminar work has been greatly stimulated and conversely, the technical sessions of the student branch have been reduced to a most effective status, with an enthusiasm and activity seldom possible in the usual manner followed in the conduct of branch meetings. These combined Seminar and branch meetings are attended regularly by about 125 students of the four classes exclusive of the instructing staff. The latter, while taking no part in the supervision of the meetings, frequently take part in the discussion which follows each paper.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

MILITARY AFFAIRS COMMITTEE

Military Policy of U. S. and Relation thereto of Technical Men

The Military Affairs Committee created by Engineering Council submitted the following communication to Council under date of February 26.

1. We believe it of vital national importance that sound Military Legislation should be enacted during the present session of Congress.

2. Effective provision for national defense with an adequate, organized, trained army and navy, sufficient to discharge our national and international obligations, is essential to security and stability, which must be present if our country is to go forward in constructive activity and achieve its possibilities as a nation.

3. The training of the entire youth of the nation and the establishment of organized reserves are indispensable provisions for national defense. With an adequate, organized citizen force, so that a minimum of professional soldiers is required, that maximum protection is afforded with a minimum of expense.

4. The careful selection and training of personnel and their assignment, when reservists, to organized reserved units, are vitally important to the efficiency of the technical services of the Army and Navy, and therefore essential to the proper preparedness of the individuals of the Engineering and allied professions and trades for the discharge of their constitutional obligations in national military service.

5. The full utilization of specially and technically qualified men and specialized industries has proved impossible where an organization was built up only after war had become imminent or had been declared.

6. The status of the membership of the National Engineering Societies with respect to all military matters, on which to base their plans for individual and collective preparedness, must remain indefinite until a military policy and principles of a military organization shall have been determined.

7. Therefore, We believe National security and stability can be assured only by application of the foregoing principles, in particular the principle of universal military training and the creation of organized reserves, above all in the technical branches.

We, therefore, recommend to Engineering Council that the President and Vice-President of the United States, the Secretary of War, the Secretary of the Navy, the Speaker of the House and the Chairmen and Members of the Military and Naval Committees of the Senate and the House be urged to incorporate the foregoing principles into any bills passed by either body for army or navy organization, and particularly the principle of universal training.

* * * *

We also recommend that each member of the Founder Societies be urged to study carefully the foregoing principles of military policy and in case, in the light of such study, he endorses said principles, to give his active support through letters to his Senators and Congressmen, or otherwise, to their incorporation in pending legislation.

These resolutions were submitted to the executive committee for approval and it was unanimously voted, to adopt the resolutions relating to the Military policy of the United States, prepared and recommended by the Military Affairs Committee.

NATIONAL SERVICE COMMITTEE

Extracts from Annual Report 1920

When the National Service Committee was constituted and the Washington office established, it was the writer's intention that the members of the committee would take a real part in the work of the Washington office and act in an advisory capacity. This plan failed. During the first few months, the writer endeavored to keep in touch with his committee and to make the members feel that they were really a part of the work. All of the members with one exception, responded promptly to all calls and demands. The trouble was that their responses were all *ex post facto*: too late to be of service. Things had to be done or omitted—they could not wait. Gradually the Chairman, in the press of his duties, forgot all about his committee and for months has not addressed them officially on any subject. The Chairman owes the members of the National Service Committee a profound apology, but at the same time he believes that his inattention has been excusable.

In one respect Engineering Council is to blame for this condition. Shortly after the National Service Committee was organized, Council passed a resolution to the effect that the Committee chairman should attend all regular meetings of Council. In this way a closer relation was set up between National Service Committee and Council than has perhaps been

enjoyed by any other committee of Council. The Washington office has been the adjunct of Council, rather than the headquarters of any committee. The Chairman of the committee has acquired the habit of applying direct to Council for instructions and advice instead of his own committee.

The name "National Service Committee" means nothing as the Washington office is at present conducted. It is recommended that the Committee be abolished. The writer believes, however, that the name "National Service" should be retained. In Washington it has been taken to mean just that which the words imply. In official circles it is understood to mean that Engineering Council offers service to the Nation, while in engineering circles it is interpreted as meaning that Council offers national service to the engineer. It is recommended that the name of the Washington office be changed to "National Service Department" and that the Washington representative be designated "National Service Representative."

It should be emphasized that the foregoing recommendations do not reflect on the members of the National Service Committee. It is apparent that, by reason of the peculiar conditions, a committee cannot function as such. The questions involved in the work are nearly always of so great importance that they must be taken direct to Council itself.

Review of Year

Engineers were very late in setting up a Washington office. Men in other vocations had preceded them in some cases by many years. About 150 national bodies have headquarters or branch offices in Washington. When Council's office was started, such a thing as organized engineering cooperation with the Government was unknown to the officials. Engineers were not regarded as interested citizens. At present, engineers are very well known at the Capital of the Nation and your organization has been rendering service there which seems to be appreciated more and more as the months go by. There are two aspects in which the Washington office may be viewed: First, it is the engineer's contribution to national welfare; second, it is the agency established by engineers by means of which they get all they can from the Government. If, in the opinion of Council, the former is the greater aspect then it will be of tactical advantage to give an expression to that effect from time to time. There is a branch office of a national engineering society in Washington the principal and frequently expressed purpose of which is to get everything possible for the engineer.

The more important matters undertaken during the year were as follows:

Mapping. Efforts to increase appropriations for U. S. Geological Survey mapping, made in June, 1919, were unsuccessful, although it is generally admitted that Council's effort to increase the appropriation was largely instrumental in preventing a marked decrease.

Increase in scope of the Geological Survey's topographic mapping next year has been undertaken by the Washington office with the cooperation of the Association of State Geologists and the Association of State Highway Officials. This work has involved the selection of some member of one of the four Founder Societies in each Congressional district of the country, who has been given the facts concerning mapping necessities and urged to undertake to interest the engineers and other parties residing within the Congressional district, so that the facts can be brought to the attention of the members of Congress in a way that will lead them to inform themselves more thoroughly concerning the needs. Just how successful this will be cannot now be determined. We are not optimistic however.

Our real accomplishment with respect to Government mapping has been the creation of a permanent Board of Surveys and Maps to which the supervision of all Government mapping has been given. This resulted from a letter from the Chairman of Engineering Council to the President.

The writer, as representative of Engineering Council and the four Founder Societies on a committee composed of unofficial organizations interested in mapping, has taken part in the preparation of a report to the Board of Surveys and Maps, which report has been submitted back to New York for approval. The principal features of that report are strong recommendations: (a) that all Government mapping be concentrated in one agency, and (b) that whenever any Government surveying party goes upon any area for purposes of mapping, however elementary, that party shall secure all the data necessary to a standard topographic map.

Appointments. The President has been urged to appoint engineers on the International Joint Commission and the Interstate Commerce Commission. There was failure in the first instance, and the result in the second has not been determined. Appointment was made in the latter case, but the President failed to consult with his appointee or ask him if it would be agreeable to present his name. The result was that the appointee has declined and the place is still vacant. The writer has made no effort to renew the request in favor of the appointment of an engineer.

Wages of Railroad Engineers. An attempt was made to secure favorable action by the Railway Administration on suitable increases in compensation of railway professional engineers. A hearing was secured before the Board on Railway Wages and Working Conditions. The American Association of Engineers was subsequently invited to take part in the proceedings. The result, so far as the Railway Board was concerned, was satisfactory, but the case was suddenly taken out of its hands. Regional Directors were instructed to use their judgment in such matters wherever compensation of railway engineers appeared to be inadequate. The writer has been informed by men in the Railway Administration who ought to know, that the real opponents to suitable compensation for professional engineers in railway work are the chief engineers; it was they who had the matter removed from the jurisdiction of the Board on Wages and Working Conditions and they who prevented the Railroad section of your Committee on Compensation from functioning. It has become apparent to some persons connected with the Railway Administration that the principal reason why professional engineers employed by railroads receive less compensation than round-house hostlers is that the chief engineers are reluctant to increase the engineers' wages and give no assistance to attempts made to achieve such a result.

Relations with Congress. The Washington office has been successful in its negotiations with Congress and with chairmen of committees having to do with engineering matters. Our failure in one instance to secure the interest of Congress in a certain piece of l gislation was due to the inertia of the very engineers in whose benefit the bill was proposed. At the close of the war, about 800 engineers were wrongfully deprived of remuneration for travel and subsistance, some of them severely so. Two separate appeals were sent out for facts concerning individual cases, but out of the 800 engineers known to have been so deprived only about 12 responded. Of course such a number is not sufficient to secure any enthusiastic action on the part of members of Congress.

The Department of Public Works. Even before the engineering and architectural societies of the country organized the National Public Works Department Association, this subject had become the overshadowing one in the Washington office, and, as indicated by the ratio of expenditures, it continued to be the principal item.

Since the last meeting of Council, the Public Works Association has held a most successful convention in Washington, the results of which in both legislative and financial respects have proved to be exceedingly tangible. Present improvement in the whole situation and the revival of interest now so readily apparent dated from that convention. On February 11, there

was a hearing before the Senate Committee on Public Lands on the Publics Works bill, at which expected opposition on the part of some bureaus and departments was conspicuous by its absence. The progress of the public works principle and the bill introduced into Congress is regarded by many members of Congress as altogether remarkable, coming as it does at a time when Congressional attention is being given almost exclusively to matters of urgent necessity, resulting from war.

Work Since December Meeting of Engineering Council

Among the important activities of the Washington office since the last meeting are:

1. The circularization of Government contractors for the purpose of securing comments and criticisms on the form of Government contracts and the interpretation of specifications, all leading up to a report on the reasons why Government work is avoided by the majority of contractors. The utility of this study will be two-fold. It will be used first by the Committee on Types of Government Contracts, and, second, by the Public Works Department Association in connection with its showing before Congress on the necessity for a standardization of Government contracts and specifications.

2. The Washington office has, on invitation, been assisting the Chairman of the new Board on Surveys and Maps, created by Executive Order, in the selection of engineers representing outside organizations for membership on the several committees appointed by the Board of Surveys and Maps.

3. In response to suggestions by the Washington office the Chairman of Engineering Council sent a letter to the Secretary of War advocating the early publication of the report of the Board of Review on War Department Construction. This letter was delivered by hand at the office of the Secretary of War and since such delivery the matter has been followed up, with the result that we are informed that the entire report will be printed as a part of a hearing before a committee of Congress.

4. The proposed Boston-Washington super-power investigation has been the subject of follow-up work. Letters were sent to 142 organizations in the region affected, calling attention to the necessity for activity in the attempt to secure a suitable appropriation as a part of the Sundry Civil Bill. This work has been carried on in conjunction with W. S. Murray. Agreement as to the representation to be made to the Appropriations Committee of Congress has been effected and it is asked that approval be given by Engineering Council. It is suggested that the committee of Council to present the matter before the Appropriations Committee consist of W. S. Murray, D. C. Jackson, L. P. Breckenridge and M. O. Leighton.

5. An appointment for a hearing before the House Committee on Military Affairs was secured on behalf of Council's committee on the maintenance of the Signal Corps of the Army. Col. J. J. Carty and H. W. Buck appeared for Engineering Council. The undersigned has rarely seen a committee of Congress so thoroughly interested in a technical matter, and in his opinion, the appearance of Col. Carty and Mr. Buck contributed largely to the prestige of Engineering Council at the Capitol.

6. Patent legislation is proceeding through the regular legislative routine about as fast as can be expected. The bill providing increased salaries for the personnel of the Patent Office has been reported out of committee and awaits a hearing before the Committee on Rules before receiving a place on the House calendar. This hearing will be held February 24. The bill providing a Court of Patent Appeals and the bill which is aimed to make the Patent Office more efficient have been reported by the subcommittees of the House Patent Committee and will be reported shortly.

7. On several occasions the Washington office has been asked to look into legislation which proposes to change the standards in the country from the English to the metric system, especially by a call from the Secretary of the Institute of Weights and Measures, who is in Washington combating this proposed legislation. The Secretary of the Institute has been introduced to the heads of Departments in the Government directly interested; your representative has been careful at all times not to express an opinion for Engineering Council.

8. The office has participated in society affairs in Washington and as a result of the enterprise and foresight of A. C. Oliphant plans are under way whereby the local engineering society, together with the sections and chapters of national societies, including the Civil, Mechanical, Electrical, Mining and Metallurgical, Automotive, and Chemical Engineers and the Naval Architects will unite in the joint organization.

9. The general work of the office has increased at about the same rate as previously. For instance, inquiries answered since the last meeting of Council number 81, as compared with 63 during the previous two-month period.

(Sgd.) M. O. LEIGHTON,
Chairman.

COOPERATION OF NON-FEDERAL ORGANIZATIONS WITH THE BOARD OF SURVEYS AND MAPS

When the meeting of the members of the Board of Surveys and Maps with representatives of outside organizations was over on March 9th, everyone who was in attendance agreed that a long step had been taken toward improvement of Governmental efficiency. This meeting was called by the Chairman of the Board, Mr. O. C. Merrill, as a result primarily of the report of the Interdepartmental Conference on Topographic Mapping, dated September 30, 1919, and in accordance with an Executive Order dated December 31st, 1919, which created the Board of Surveys and Maps, and directed it to receive advice and counsel of outside agencies interested in the mapping work of the Government.

The report of the Committee of Representatives of the outside organizations interested in Government mapping was presented by M. O. Leighton as representing the member societies of Engineering Council and as secretary of the Committee, which membership includes the above organizations and the American Association of State Highway Officials, Association of American State Geologists, National Research Council, Association of American Geographers, American Geographic Society and Geographical Society of America.

In introducing this subject Mr. Leighton warned the Board that while efficiency and economy in centralized mapping operations were most commendable, there are certain occasions when strict application of the accepted principle would deprive some Government agency of its mapping prerogatives. The consideration of the Board in such cases would have to be in a large degree judicial and representatives of the interested department should be disqualified from participating in decisions affecting that department. Further, it was suggested that a plan should be adopted by which cooperating non-federal agencies could have a voice in the determination of the manner and place of disbursement of their contributed funds.

The following recommendations were then made with appropriate amplifications and explanations:—

1. That the Board of Surveys and Maps adopt a policy that shall direct itself exclusively to the best interests of the Government as a whole, disregarding wherever necessary, departmental and bureau precedents, pride or authority of official prerogatives; that the mapping activities of the Government be centralized, and for the present the U. S. Coast and Geodetic Survey continue its functions of fundamental control, while the Geological Survey or some outgrowth or reorganization thereof become the general and the final map-making agency.

2. That the Board of Surveys and Maps formulate a consecutive plan based on the idea of centralized map making activity, which shall cover the mapping work of the Government and unite the organizations now constituting the Board into a cooperative effort to secure congressional approval, which plan shall provide for the completion of the standard topographic map of the United States within a specified time.

The report contained comments concerning the following special features of the conference report:—the preparation of skeleton maps of various scales, which would decrease the costs and increase the efficiency of all Government offices and outside agencies concerned, so as to more than compensate for the loss of strong self-contained organizations; methods of distribution should contemplate the size of additions, costs, methods of distribution and should eliminate the "make ready" costs as well as making the maps available with the least amount of effort on the part of the public; suitable maps for educational institutions should be provided and instructions issued for their utilization with appropriate courses. Assistance should be given in the improvement of popular maps and atlases; coordination of Federal and Non-Federal datum reference points should be effected as soon as practicable. The Board should not depart from its standardized maps except by special agreement with the interested agencies whenever the need of such maps arises.

Following the presentation of the above report, the need of a general topographic map of the United States and means by which its preparation may be expedited was covered from the highway standpoint by a representative of the Director of the Bureau of Public Roads; from the railway standpoint by A. C. Baldwin, Vice-President of Illinois Central Railroad; from a military standpoint by C. O. Sherrill, Colonel, Corps of Engineers, U. S. Army; and in general by George Otis Smith, Director of U. S. Geological Survey, and Major William Bowie, Chief of Division of Geodesy, U. S. Coast and Geodetic Survey. The extent and means of cooperation between the Board and other agencies was covered by Mr. A. D. Flinn, Secretary of Engineering Council; Edwin F. Wendt, District Engineer, Interstate Commerce Commission; F. W. DeWolf, State Geologist of Illinois. The public needs which a central information mapping office may serve was covered in detail by E. B. Matthews, Chairman of Division of Geology and Geography, National Research Council.

It will be recalled that the development of this Board of Surveys and Maps through the Interdepartmental Conference on Topographic Mapping was brought about largely by action of Engineering Council in bringing the chaotic mapping conditions in the Government to the attention of the President, with recommendation that such agency be formed. The developments of this last meeting indicate that the Board will not sidestep the task of making over these vast departmental operations. During the discussion that followed the report, the Board was repeatedly assured of real cooperation from outside organizations provided they would approach the committee already formed or such new committees as were deemed wise, with well defined problems to be solved.

CURRENT ENGINEERING TOPICS

STATUS OF THE PLAN FOR DEFERAL BUDGET

After the House of Representatives passed Mr. Good's Budget Bill to the members of the Select Committee on the Budget in the Senate, each took this question up separately and made recommendations for extending and changing the bill to meet their ideas.

A new bill has been recommended and agreed upon by the Senate committee, so that it will be reported to the Senate calendar early in April.

Engineers will recognize that this is important legislation, vitally effecting Government reorganization,—it goes along hand in hand with the engineers' bill,—Jones-Reavis Bill to create a National Department of Public Works. The plan for departmental budget is embodied in the proposed Public Works Department so that the new department when formed will contemplate at least the fundamentals proposed in this national budget legislation.

CONTINUATION OF THE NATIONAL SCREW THREAD COMMISSION

A resolution passed the House of Representatives March 1st, amending the act that created the National Screw Thread Commission, so that the life of this commission will be extended for an additional period of two years from March 21, 1920.

The resolution has been referred to the Committee on Standards, Weights and Measures in the Senate, and although meetings have been called to consider this measure, Senator James M. Reed, chairman of the committee, has been unable to get a quorum present. It is contemplated that this measure will receive early action as soon as the Senate is able to clear up its present calendar.

ARMY REORGANIZATION BILL

The Army Reorganization Bill passed the House March 19, providing for continuation of Chemical Warfare Service and a strong Signal Corps. The amendment to maintain separate Construction Corps which had been passed March 12, by a vote of 135 to 74, was reversed by a vote of 168 to 158. The present status of the bill will retain Construction Corps and Motor Transport Corps in the Quartermaster Corps.

MACHINE TOOLS FOR THE FRENCH AND BELGIAN COMMISSIONS

Some manufacturers have been informed that private credits on machine tools required by the French and Belgian Commissions could be arranged through the War Department. This is not the case and the War Department has issued advice that it is in no way connected with negotiations which are taking place between these Commissions and private manufacturers. The War Department has, however, agreed to permit the French to take such surplus tools as they require on credit. The Director of Sales in the War Department has pointed out that his office is anxious to be of service to the American manufacturers, the French and Belgian Commissions in rounding out their needs, but private purchases of the Commissions can in no way be financed by the Government. The French Commission alone has purchased machine tools in the United States valued at over $1,000,000 and much heavier purchases are expected to follow shortly. Most of these purchases were made through the New England districts, whereas the West has supplied comparatively few. An invitation has been extended by the St. Louis interests, asking the Commission to visit that city where considerable quantities of tools are available.

Such sales as the War Department has been able to make the Commission have all been at domestic prices, the purchaser paying for crating, loading and transportation.

Complete lists of additional tools required by both the French and Belgian Commissions may be obtained from the National Service Department of Engineering Council.

STATUS OF WATER POWER BILL

Two important points of difference existed between the House and Senate conferees on the Water Power Bill when they adjourned March 9th for a period of at least two weeks. The adjournment was taken to await the return to Washington of Representative Taylor of Colorado, and permit Senators Jones and Smoot to devote some time to the Merchant Marine and Executive Bills, respectively, both of which are now pending.

Agreement may be expected shortly after this issue goes to press. Hope was expressed that the conferees would get together after a short discussion but this hope was not realized, although the friends of water power development regard the situation as very satisfactory. The remaining points of difference, which have delayed agreement, are those pertaining to license charge and recovery and the proposal to have an Army engineer as Executive Secretary. The strong opposition to

this plan will probably result in placing a civilian in that office with the authority to have an engineer officer detailed to assist in the work.

The power project for Great Falls on the Potomac River, which carries an appropriation of $25,000,000 and was placed in the bill as a rider by the Senate, was eliminated in conference. No announcement was made concerning the other items, but it is believed that the Newland's investigating provisions will be eliminated.

A CALL TO INSTITUTE MEMBERSHIP TO ASSIST IN PATENT LEGISLATION

As a result of the efforts of Mr. Edwin J. Prindle and his colleagues, the Nolan Patent Bill was put on the House calendar for March 5th. It passed the House of Representatives by a substantial margin that day.

Mr. Prindle is chairman of the Patent Committees of both Engineering Council and National Research Council. It will be recalled that extensive hearings were held before the House Patents Committee so that the case presented to the Judiciary Committee consisted simply in urging immediate consideration for the Nolan Patent Bill. About sixty engineers, all of whom were members of the Founder Societies or representatives of organizations using the Patent Office extensively, supported Mr. Prindle. When the hearing was over, the chairman of the Judiciary Committee told these men that it had been the most satisfactory hearing held by his committee in over ten years and that the thorough disinterested manner in which the engineers had presented their case assured early action in the House. This assertion was borne out when the House passed the bill a few days later.

The bill (H. R. 11984) as it passed the House provides for an increase in salaries and staff of the Patent Office and certain other amendments to the present statutes. The salaries of the principal Examiners are to be raised from $2750 to $3900. The bill also authorizes the courts to assess general damages under certain conditions in infringement suits.

The members of the Patents Committee of Engineering Council have expressed their opinion that it is of the utmost importance that the force and salaries of the Patent Office be promptly increased.

The bill is now before the Senate Patents Committee where it is intended to hold short hearings and send the bill on its way as soon as the Treaty Legislation can be disposed of.

Please write immediately to your Senator urging that he vote in favor of the bill, and thus aid in obtaining a much needed relief.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

ILLUMINATING ENGINEER for work in industrial lighting problems for contracting and electrical engineering firm. Man with wide industrial and some sales experience desired. One who would consider compensation on salary and commission basis, preferred. Location Toronto, Canada. Z-584.

MAN TO TAKE CHARGE OF SHOP building motors for phonographs. Should be capable of taking entire charge of production and bringing same down to best and most economical commercial manufacturing basis. Location Brooklyn. Salary $5000 to start, and if man demonstrates capacity and ability to handle job satisfactorily, will gradually increase this to $10,000. Z-587.

ENGINEER to handle questions of power plant operation including electrical generation, refrigeration, compressed air and vacuum pumping and boiler plant. Location New York at present. Z-604.

ELECTRICAL DRAFTSMEN and Designers for work in connection with transmission lines, substation equipment, switchboards, motor control equipment, etc. Location Ohio. Z-613.

PERSONAL ASSISTANT to chief engineer of power and electric company. Would have to do calculating on special electrical engineering problems. Man pretty well versed in mathematics and electrical calculations desired. Practical experience not necessary but applicant must possess good sound judgment and initiative. Location Mass. Z-625.

ELECTRICAL ENGINEER for firm of Consulting Engineers. Requirements; five years minimum experience since graduation from technical school embracing design and preferably also construction and operation of power plants, transmission, and distribution system. Duties—largely office work on design although field inspection and tests are demanded occasionally. In making application give detail record of experience including personal data, salary required, date for reporting. Commensurate with value of experience salary range will be from $252 to $333 per month. Mees & Mees, 310 Trust Bldg. Charlotte, N. Car. Z-627.

LARGE NEW ENGLAND MANUFACTURER of electrical apparatus wants young men with some experience in drafting who desire to improve their opportunities. To such as have good high school education and some technical training but who for some reason were not able to complete their technical course, we offer opportunity to work as draftsmen at good wages and at the same time, without expense, attend courses of instruction to prepare them for positions here as calculators or desingers of electrical apparatus or specialists in sales organization. Location Mass. Z-628.

SALES ENGINEER young man with some college or technical school education to ultimately be assigned to sales force, after taking course at factory in engineering department. General laboratory and experimental work to begin with, together with computing of layouts, and proposals for lighting, costs, and maintenance. This will take year or little longer and will give candidate full opportunity to learn lamps thoroughly and be conversant with their uses and ultimately fit him for outside sales engineering work. Salary $100-125 per month to start. Location New Jersey. Z-658.

ELECTRICAL DRAFTSMEN for substation work; (B) TRACER for same line work. (C) ASSISTANT ELECTRICAL ENGINEER for squad boss on substations work; Must have good personality. Location vicinity of New York City. Z-670 A-B-C.

FIRST CLASS ELECTRICIAN. Salary $225 gold at the beginning, with transportation. Spanish desirable but not essential. Address C. C. Hoke, Mapini Dgo, New Mexico. Z-677.

EXPERIENCED SWITCHBOARD OPERATOR for hydro-electric station. Salary $115 per month, eight hours, location New England. Give experience, age, references, whether married or single. Z-678.

ENGINEER MATHEMATICIAN AND PHYSICIST; salary commensurate with ability. Location Mid le West. Z-681.

ELECTRICAL, MECHANICAL, AND CHEMICAL ENGINEERING MEN of 1920 class or those that have not been away from college more than two or three years at the most. Company is planning considerable expansion in incandescent lamp industry within next five years and believe that opportunity for advancement for engineering men will be particularly good. Starting salary will probably range from $1500 to $1800 per year depending entirely upon experience and training. Location New Jersey. Z-684.

DRAFTSMEN to lay out wiring for lighting and power work for various types of buildings. Must be familiar with this kind of work and have had experience, either with some electrical engineers or with some electrical contractors. Location New York City. Z-687.

EXPERT ACCOUNTANTS; must be between ages of twenty and forty, and have had considerable accounting experience, or have graduated from an accounting school. Salary commensurate with ability. Location New York State. Z-724.

ELECTRICAL ENGINEERS who have had technical training and who are familiar with application of electricity in coal mining, power plant operation, and who have had experience in building up an organization. Duties will include maintenance of large amount of electric equipment in the mines, supervision of 5,000 KW Generating Station, and handling of the entire electrical organization at colliery. Salary $3,300 per year. Location Pennsylvania. Z-727.

RECENT GRADUATE ENGINEERS or those but one or two years out of college for apprenticeship course in manufacturing plant lasting from six to nine months. Broad gauge men desired. Will pass through various departments of plant to get an insight into the business and will then be assigned to production, cost, or management engineering work. Salary $125 per month with increase to $150 after 9 months. Location Penn. Z-736.

RECENT GRADUATES in mechanical, electrical or chemical engineering. Good future. Salary $2500 and expense. Location India. Z-737-B.

GRADUATE ELECTRICAL ENGINEER for installation, maintenance and selling of an electrical neutralizing devices for printing plants. Must not be afraid of work, and must also join union in order to do installation work. Location New York City with some traveling. Z-741.

INSTRUCTOR IN MATHEMATICS for next school year at Brown University. Essential that candidate have had either experience in teaching or good mathematical. Engineering experience would be valuable addition to man's qualifications. Should be young man imbued with high ideals and possessing some social graces. About fourteen hours of teaching would be expected. Salary twelve to eighteen hundred dollars for first year. Location Providence, R. I. Z-761.

GENERAL SUPERINTENDENT at least 35 years of age, with extensive experience along executive lines to take charge of operation of electric railway, power and light company serving from 12,000 to 15,000 customers, and operating about 100 miles of street railway. Need not necessarily be a technical graduate but such training would be of advantage. Must have had railway and power and light experience, but above all must be an excellent manager and executive. Location Pennsylvania. Z-801.

ENGINEER EXPERIENCED in electric railway roadbeds and equipment. Must have had technical and practical experience and be at least 35 years of age. Position is one to be created in an organization operating 100 miles of street railways and serving 12,000 to 15,000 customers, with light and power. Location Pennsylvania. Z-802.

ASSISTANT ELECTRICAL ENGINEER for large manufacturer of excavating machinery. Duties will include application and arrangement of electrical equipment, such as—motors, magnetic control, transformers, motor generator sets, wiring, etc. to electric shovels, dragline excavators and dredges. Technical man with electrical and mechanical experience desired. Salary $125-175. Z–817.

ELECTRICAL ENGINEER; permanent position open for graduate engineer, preferably Canadian familiar with Ontario. Intimate knowledge of interurban electrical railway equipment and operation essential. Apply Employees Relations Department, Hydro-Electric Power Commission of Ontario, 190 University Avenue, Toronto, Canada. Z-818.

YOUNG ENGINEER if sound technical training desired in connection with the development of new high frequency electrical apparatus. Good grasp of physical and mathematical fundamentals important. Signal Corps experience useful. Permanency assured. Location New York City. R-2405.

JUNIOR RESEARCH ENGINEER; a long established industrial organization in a rapidly expanding field has an attractive opportunity for a young man of first-class ability and thorough training in electrical engineering or technical physics. Postgraduate training desirable but not insisted upon. Prospects limited only by ability. Salary proportionate to education and record. Location New York City. R-2406.

DEVELOPMENT ENGINEER; young engineering graduate wanted for experimental development work on electrical apparatus. Distinctive opportunity for young man of energy, resourcefulness and supervisory capacity to grow with new engineering developments of a fundamental nature. Salary determined by qualifications. Location New York City. R-2407.

SALES ENGINEERS; young men, preferably with mechanical or electrical education and training, although any technical graduate would be considered. Not much sales experience necessary, but men must possess sales potentiality. Salary $150 up depending upon, qualifications. Location New York City. Application by letter with which should be enclosed recent snapshot. Z-193.

ELECTRICAL ENGINEER experience in design of D. C. Generators and Motors of medium and large size. Must be technical graduate, and have had about five years design experience. Permanent position with opportunity for advancement for qualified designer. In applying, state education and practical experience since graduation. Location Pennsylvania. Z-340.

RECENT GRADUATES OF MECHANICAL OR ELECTRICAL ENGINEERING COURSES for engineering work connected with production of electrical and mechanical devices. Send application to Mr. J. C. Wilson the Cutler Hammer Mfg. Co., Milwaukee. State training, experience in industrial plants, if any, references and other information concerning yourself. Z-476.

UNIVERSITY OF WISCONSIN, ELECTRICAL ENGINEERING DEPARTMENT, desires to appoint an assistant or associate Professor of Electrical Engineering qualified to assume charge of the Central Station and Electric Railway Courses. An experienced engineer who has carried on investigative work resulting in contributions to the art is desired. R-2080.

ELECTRICAL ENGINEER with experience on transformer design. Splendid opportunity. State age, education, and practical experience when applying. Z-827.

MEN AVAILABLE

Notices are published in this column subject to the following regulations:—

1. Copy should be limited to 45 words.
2. The form should be such that the initial words indicate the classification.
3. Copy should be on hand by the 15th of the month preceding date of issue.
4. Notices are not repeated in consecutive issues.
5. Only notices of society members (or those introduced by society members) will be published.

GRADUATE MECHANICAL ENGINEER; married, twelve years of exceptional broad practical experience, technical apprentice machinery course, shop, office, sales, factory estimating, inspection, salvage, inventory and appraisal; purchasing and export experience; inspection and testing; erecting engineer; production engineer; appraisals expert. Familiar with Latin America and its people. Salary depends on location. Available thirty days notice. E-2097.

ELECTRICAL-MECHANICAL MAN; experienced as chief electrician, chief draftsman, assistant mechanical engineer, plant engineer and head of department of instruction. Understands manufacturing, installing and operating field or small electrical-mechanical machines. Correspondence school and Alexander Hamilton Institute courses. American; married; 28 years; prefer Eastern states, would consider Middle West. E-2098.

ELECTRICAL ENGINEER; technical graduate; age 31; experienced in design, construction, operation and maintenance of large hydro-electric plants; high tension transmission systems; high tension transformer and switching stations; rotary converter substations and large industrial electrical installations. Location unimportant. Salary $4000. Available on 30 day notice. E-2099.

INDUSTRIAL PHYSICIST; age 29, married and in excellent health, desires position as chief physicist, or as assistant to physicist of national note. A.M. and Ph.D. degrees in physics and mathematics. Two and one half years practical research in engin ering laboratories of large corporation. Present salary $300. Available 30 days notice. E-2100.

EXECUTIVE-ELECTRICAL ENGINEER; four years factory management and industrial investigation, fourteen years public utilities and industrial engineering, including syndicate operation of small utility companies. Technical graduate, age forty two. Available on reasonable notice. Minimum salary $4000. Positions with future possibilities, only will be considered. E-2101.

ELECTRICAL AND MECHANICAL ENGINEER; age 42; 19 years experience on high and low tension apparatus, switching equipment, sub-stations and underground work. Last 10 years supt. in charge of construction, maintenance, and operation of 160,000 H. P. plant. Has also some industrial plant experience. Available any time. E-2102.

FACTORY MANAGER; of auto tire and tube plant desires to connect with well financed company manufacturing similar line. Age 33 years, graduate Mass. Institute of Technology. Thorough knowledge of rubber compounding and manufacturing methods. Excellent references. E-2103.

AMBITIOUS YOUNG MAN; age 23, electrical school graduate, with one year of construction and repair and with three years of marine and maintenance experience, desires opportunity which may lead to executive position. Associate. E-2104.

ASSISTANT ENGINEER; age 25, married; technical education; 5 years experience in contracting, testing and construction. Last two years with electric traction company on substation construction work, comprising general supervision of switchboard construction. E-2105.

TECHNICAL GRADUATE; age 29, desires position as assistant to Electrical Engineer or Superintendent. Seven years experience in the maintenance and operation of power houses. E-2106.

ELECTRICAL AND MECHANICAL ENGINEER; 20 years' experience; is capable designer and has inventive ability. Can take charge of or organize efficient drafting force; specialties are elevators, motor control apparatus and automobile equipment. Location, Newark or Vicinity. Age 41. Minimum salary $4000. Excellent references. E-2107.

SALES EXECUTIVE; 43 years old; married; 20 years successful sales experience, 15 years in electromechanical lines. Competent sales and business executive, special experience in motors, generators, storage batteries and applications. Prefer location in Philadelphia or Chicago. Formerly manufacturers' agent in Chicago. Now in War Work. Available May first. E-2108.

ELECTRICAL ENGINEER; graduate in engineering, also Emerson Efficiency course; 16 years experience as assistant or chief electrical engineer; specialist on industrial power systems and transmissions up to 66,000 volts including design, construction and operation, desires engagement as electrical engineer with industrial concern or as industrial power specialist with power company. E-2109.

YOUNG ELECTRICAL ENGINEER; university graduate; experienced in hydro-electric power plant operation and pole line construction, desires position with hydro-electric power company where there is good chance for advancement. Available in July. E-2110.

ELECTRICAL ENGINEER; technical graduate, age 27, married; at present employed in consulting engineering office, desires change. Four years varied experience covering tests of electrical equipment, installation, maintenance, and calibration of electrical measuring instruments; standardization work; investigations of transmission and distribution systems. Location preferred, East. Minimum salary $2,100. E-2111.

ELECTRICAL ENGINEER; age 28, married; desires position with commercial or engineering establishment. At present Asst. Professor of Electrical Engineering, 1915 graduate. Five years valuable experience; Westinghouse test. Work considered where engineering training can function and where future exists. Location anywhere, middle west perferred. Available June 15. E-2112.

GRADUATE ELECTRICAL ENGINEER; M. I. T. 1918, age 25; Associate Member; 14 months General Electric test work, including A. C. and D. C. rotating machinery, steam turbines, transformers, and control apparatus. Desires position with power company. Available at once. Location unimportant. E-2113.

GRADUATE ELECTRICAL ENGINEER; specialty radio engineering with one year's experience in radio inspection, and installation of commercial equipment, and two year's experience as instructor in radio theory desires position after July. Associate member A. I. E. E. and I. R. E. Salary $150 to $175 depending upon locality. E-2114.

ELECTRICAL ENGINEER; technical graduate of highest standing, one year as second lieutenant, Signal Corps, one year in development work for electrical manufacturer; desires connection where personality as well as technical ability can be capitalized, preferably in sales organization of electrical manufacturer. Salary not less than $2400. E-2115.

ELECTRICAL ENGINEER; graduate 1912, desires position in hydro-electric power development, with consulting engineers, or in industrial plant. 8 years experience with large industrial corporation having extensive hydro-electrical generating, rotary convertors and distribution systems. Age 31, married; minimum salary $300 per mo. E-2116.

ELECTRICAL ENGINEER; A. B. and E. E.; seven years experience in practical work, covering central station, substation and isolated plant construction and maintenance; two years head of department of electrical engineering in state university, desires teaching or commercial position. Age 32, married. Minimum salary $3500. Present salary too low. E-2117.

ELECTRICAL-MECHANICAL-HYDRAULIC SALES ENGINEER; graduate degree Ph. B. in E. E.; 22 years in field as chief engineer and manager salesmen etc. for domestic or export. Foreign station acceptable; 2 years in U. S. Engineers; officer in charge constru tion in France, 18 months experience in pumping, steam, hydraulic and all mechanical lines. E-2118.

ELECTRO-MECHANICAL ENGINEERING GRADUATE; 25 months General Electric Co. test; 20 months inspection work at large shipbuilding plant; desires position in or near New York City as sales or assistant industrial engineer with good opportunity for advancement. Available on 30 days' notice. Salary $200 per month. E-2119.

TECHNICAL GRADUATE; two years G. E. test; eighteen months construction; one year second lieutenant signal corp; one year electrical instruction in large middle western university; desires position as works electrical engineer, central station superintendent, or assistant factory manager. Salary $2400. Available June 1st. E-2120.

INDUCTION MOTOR DESIGNING ENGINEER; thirty-four; ten years actual experience with four most successful motor manufacturers, now open to offer. If you need a real engineer, conversant with every phase of the game, theoretical and practical, do not pass this up. Salary about $4000. E-2121.

ELECTRICAL ENGINEER; technical graduate; five years in charge of transmission, distribution, substation and switchboard design and construction; three years with large public utility company; at present in charge of electrical reconstruction of large property, desires position with progressive organization that is willing to pay for results. Salary $3600 to $4000. E-2122.

PROFESSOR OF ELECTRICAL ENGINEERING; wishes to make change in position at end of present school year. Will consider teaching or commercial position in any section. Age 35. Broad training in engineering, research, and teaching. At present head of an electrical engineering department. Minimum salary $4000. E-2123.

ELECTRICAL ENGINEER; age 30, technical graduate with 7 years experience in public utility work from test to department supervision. Experienced in construction, operation and maintenance of steam and hydro-electric plants, distribution and transmission systems. Available on reasonable notice. E-2124.

SUCCESSFUL ELECTRICAL ENGINEER; of several years practical and teaching experience desires teaching position with considerable amount of executive work. Age 35. Member. Salary $3200. E-2125.

ELECTRICAL ENGINEER; graduate; married; excellent experience in electrical and efficiency engineering. Calculation, power plant and transmission construction, large motor applications, transportation, investigations, reports and installations of mining and industrial power projects. Good executive. Services available on short notice. Correspondence invited. E-2126.

SALES ENGINEER; age 36; technical education, considerable practical experience, wiring layout and installation; design and manufacture of conduit fittings, wiring devices, lighting equipment and artistic fixture parts. Broad selling and advertising experience to electric dealer, jobbing and central station trade, industrial, household, marine and railroad consumers. Now in manufacturing business. E-2127.

EXECUTIVE; broad engineering and business esperience, age 34, university training, engineering and law; conversant with wide range, large construction and operation work, also machinery, their specification and manufacture. Experience shop work, cost accounting, purchase, sales and office management. Accustomed vast amount detail. Now holding responsible position. E-2128.

ELECTRICAL ENGINEER; technical graduate, age 43, open for position. Familiar with power plant work, power transmission and application. Experienced in installation, operation and maintenance of steam and electrical machinery and electric car equipment. Able to take hold and get results. E-2129.

ELECTRICAL ENGINEER OR CHIEF ELECTRICIAN; age 33; married; trade school graduate; experienced on estimating, installation and maintenance of electrical machinery 75 H. P. and under, transmission up to 11000 volts; duct systems and electric arc welding; present position 3 years at $2000 per year as Inspector on large steam and electrified railroad. E-2130.

RESEARCH MAN; university graduate electrical engineer. Teaching, G. E. test and experimental experience. Practical ability in research procedure and initiative in applying principles of physics to new situations. Now engaged in research work on factory processes for large manufacturing company. Desire middle western location. Salary $2400. E-2131.

ELECTRICAL ENGINEER; with two years experience in designing D. C. motors, desires position either designing or operating. Salary $2500 to start. E-2132.

ELECTRICAL ENGINEER; desires position in Eastern Ontario, Canada. At present chief electrician large by-product coke plant. Ten years general steel mill construction and operating experience. Thorough knowledge of motor repair work A. C. and D. C. and magnetic control. Ability to handle men; also to specify and purchase electrical equipment. Salary $3000. E-2133.

ELECTRICAL ENGINEERING GRADUATE; 1919 B. S.; age 23, single desires position in engineering department of concern manufacturing electrical machinery or power supply company. Two years testing experience on D. C. machinery. Salary $1500. E-2134.

ENGINEER; of twenty-five years experience, technical graduate (M. E., Sc. D.) who has been teaching during past ten years, desires to return to commercial field. Broad experience along lines of power-plant and machine design. Ability to take responsible charge of high grade work. E-2135.

SALES ENGINEER AND EXECUTIVE; technical graduate; age 30, will consider high grade proposition to establish connections with right kind of successful men. 10 years experience, consisting factory work, testing, construction, central station, railway, industrial plant and electric furnace, sales. Available on short notice. E-2136.

ELECTROCHEMIST; experience in manufacture of metal, metal-graphite, graphite, and carbon brushes, small electrodes and other carbon products. Technical graduate with ten years experience. Capable of taking entire charge of factory. Can design special machinery and furnaces. At present employed. Single, age 31, will go anywhere. E-2137.

GRADUATE ELECTRICAL ENGINEER age 28; single; wishes to become associated in work of commercial character, sales engineering preferred. Six years experience, including two years operation and maintenance of electrical equipment, four years office engineering work on power equipment. Executive ability; good correspondent; retentive memory. Available 30 days' notice. E-2138.

TELEPHONE ENGINEER; 30 years old. Six years with Western Electric Company. Experience includes student course, experimental and development work on semi-automatic and manual systems. Salary $2500. Services available in thirty days. Location desired, California. E-2139.

EXECUTIVE ENGINEER; employed ten years by leading manufacturer as research, design, and application engineer desires to become affiliated with active sales or works organization where broad engineering experience will serve as basis for larger activities. E-2140.

MECHANICAL OR PLANT ENGINEER; technical graduate, excellent executive, successful in handling all classes of men, diplomatic and tactful. 18 years experience in electrical and mechanical engineering including installation and maintenance; industrial plant, power, heating and lighting layout; organization and production engineering and purchasing. E-2141.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities, is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—John McF. Fisher, Arapoho, Oklahoma.
2.—J. P. Gailunas, 100½ Van Couver Avenue, Detroit, Mich.
3.—Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.
4.—George L. Sewell, Porter Bros., Norfolk, Va.
5.—W. A. Street, Gatun, C. Z.
6.—Lieut. W. J. Strieby, 34 Simpson Road, Ardmore, Pa.
7.—Lieut. T. W. Swartz, 53 D. Infantry, Chattanooga, Tenn.
8.—A. S. Touche, 72 West Adams Street, Chicago, Ill.
9.—R. M. Umberger, 504 West King Street, Lancaster, Pa.

PERSONAL

R. E. UPTEGRAFF has discontinued his services with the Adams-Bagnall Electric Co. of Cleveland, Ohio, and will again take up his work in Pittsburgh with the firm of Rutherfoord & Uptegraff, Consulting Electrical Engineers.

GEORGE M. OGLE, formerly Chief Electrical Engineer of the United States Shipping Board, Emergency Fleet Corporation, is now a member of the Engineering Organization in charge of the Electrical Contracting and Consulting Engineering Department of the Vulcan Iron Works, Inc., Jersey City, N. J.

WALTER J. SEELEY, recently appointed to an Instructorship in Electrical Engineering at the University of Pennsylvania, is a graduate of the Polytechnic Institute of Brooklyn, in the class of 1917. For two years following his graduation, Mr. Seeley was engaged in research and development work on submarine detection as an Ensign in the Navy, at New London, Conn., and at Plymouth, England.

C. H. ELSOM, formerly Secretary of the West Va. Engineering Co., Charlotte, West Va., announces that the Mullens Light & Power Co., Mullens, West Va., has recently been purchased and a new company, the Union Power Co., incorporated, of which he is President. Extensive improvements are contemplated among which is a thoroughly modern street lighting system for the city. The main offices are located in Charleston, West Va.

RICH D. WHITNEY, Associate Professor of Electrical Engineering, Syracuse University, and formerly Consulting Engineer of the Bureau of Water, City of Syracuse, has resigned from these positions to accept a position with the H. H. Franklin Manufacturing Company of Syracuse, where he is to be attached to the office of the Factory Manager on Special Assignments.

He left the employ of the city March first, and will leave the University at the close of the present college year.

Frank H. Bernhard, formerly managing editor of *Electrical Review*, has resigned this position to become editor of the E. M. F. Electrical Year Book. Mr. Bernhard, a graduate of Armour Institute of Technology, had some practical engineering experience and several years experience in teaching Electrical Engineering prior to his work for twelve and one-half years on the editorial staff of *Western Electrician*, later of *Electrical Review and Western Electrician*, and of *Electrical Review*. His new business address is 1018 South Wabash Avenue, Chicago.

George E. A. Fairley, for five years Assistant Chief of the Electrical Commission of the City of Baltimore, Md., has received a promotion to the grade of Lieut. Colonel, Reserve Corps of Engineers, U. S. A. Colonel Fairley served fifteen months in France, in command of a Battalion of Engineer troops, and for six months was Electrical Engineer Officer in charge on Construction, in the Intermediate Section, west, and the City of Paris District, with headquarters at Gievres, Loir et Cher. This district contained the large camps of LeMans, St. Aignan, Gievres, Romorantin, Mehun, Tours, Montierchaume, and Issoudoun.

H. R. West, recently appointed Instructor in the Electrical Engineering Department at the University of Pennsylvania, is a graduate of the University of South Dakota with the degree of M. A. He was a fellow in physics at the University of Michigan in the year 1916-1917, after which he was employed in the transmission engineering department of the Bell Telephone Company of Pennsylvania. During the war he served in the operation and maintenance department of the Hog Island Shipyard, and later in submarine detection work as an Ensign in the Navy, being detailed to the Naval Experimental Station at New London, Conn.

Chas. D. Fawcett, recently appointed Assistant Professor of Electrical Engineering at the University of Pennsylvania, is a graduate of the University of Colorado, and served as instructor at that institution for one year. For two years he worked in the testing department of the General Electric Company, and for several years served as Instructor at the University of Pennsylvania. In 1916 he was appointed Assistant Secretary of the Illuminating Engineering Society with headquarters in New York. During the war, he served as illuminating engineer for Monks and Johnson, and subsequently was the authorized representative of the Emergency Fleet Corporation in charge of the construction and operation of the Ship Steel Fabricating Plants at Pottstown and Leetsdale, Pa.

OBITUARY

Albert Percy Chapman died on March 18, 1920, following an illness of eight days of double pneumonia. Mr. Chapman was born in Springfield, Mass., February 5, 1883, and was a graduate of the Springfield High School and Worcester Polytechnic Institute. In 1914 he went to Ludlow, Mass., to take charge of electrical work for the Ludlow Manufacturing Associates, and became Superintendent of power and repairs in 1917, which office he held at the time of his death. He joined the Institute as Associate in 1906, and became a Member in 1917.

Leslie H. Harris, late Professor of Electrical Engineering at the University of Pittsburgh, died February 21, 1920. Prof. Harris was born in Bradford, Pa., October 23, 1883. In 1907 he was graduated in Electrical Engineering from Purdue University, following which he had a year's experience with the Westinghouse Elec. & Mfg. Co. From then until the time of his death he was in the Electrical Engineering Department of the University of Pittsburgh, except for the period of war, during which he was in service as Major, Q. M. C., Newport News, Va. Prof. Harris became an Associate of the A. I. E. E. in 1911, and a Member in 1912.

R. L. Cadwell, late Superintendent of Construction for the Department of Development of the Georgia Railway & Power Company, died at his home near Tallulah Falls, Ga., February 16, 1920. Born in Arizona in 1884, Mr. Cadwell received his education and early technical experience in the West. He first became associated with the Georgia Railway & Power Company in 1911 as Superintendent of Construction for the original Tallulah Falls Development under Mr. Chas. G. Adsit, then Chief Resident Engineer, having been associated with Mr. Adsit in several similar undertakings out west and in Mexico prior to his connection with this company. After the completion of the Tallulah Falls Development, Mr. Cadwell returned to the West to identify himself with some mining and copper smelting projects in Arizona, but severed his connections with these interests in the early part of 1918 to accept the position he held at the time of his death. He was a Construction man of unusual ability and wide experience, and his associates feel that his death leaves a vacancy which it will be difficult to fill. He died as a result of Pneumonia, which set in after an attack of Influenza.

Henry Smith Carhart, formerly a member of the Institute, and a recognized authority in electrical science, died suddenly, from the effects of cerebral hemorrhage, at his home in Pasadena, California, February 12, 1920. Dr. Carhart was born at Coeymans, N. Y., March 27, 1844, and was graduated from Wesleyan University in 1869. He studied at Yale 1871-2, Harvard 1876, and University of Berlin 1881-2. Wesleyan University conferred on him the degree of LL. D. in 1893. From 1872 to 1886 he was professor of physics and chemistry at Northwestern University, after which he was professor of physics at the University of Michigan until 1909, and since that date emeritus professor with the same institution. The year 1881 in Berlin was devoted to research work in the laboratory of Professor von Helmholtz, which was the beginning of investigations on voltaic cells, later developed into the production of a standard cell, involving work at the Bureau of Standards in 1910. He had been largely instrumental in establishing this Bureau through the medium of his paper presented at a meeting of the Institute in 1900 on "The Imperial Physico-Technical Institution in Charlottenburg." Dr. Carhart also contributed other papers to the Institute and many articles to technical periodicals, and was the author of various text books. He was a member of national and international committees, and served as delegate at scientific conferences. Notwithstanding his advanced age he maintained his interest in scientific work in recent years, by his intimate relations with the California Institute of Technology, formerly Throop, at Pasadena, Cal., where his appointment as research associate in physics was a great stimulus to that institution.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES FROM FEB. 1-28, 1920

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AMERICAN GAS WORKS PRACTISE.

Standard Practical Methods in Gas Fitting, Distribution and Works Management. By George Wherle. N. Y., Progressive Age Publishing Co., 1919. 741 pp., illus., tables, 8 x 6 in., cloth, $4.00.

This work is intended as a general reference book on gas works practise in this country, with special emphasis on gas fitting practise. Approximately, one half of the book is given to the latter topic, and the methods used in street and house distribution, standards adopted, etc., are fully described.

APPLIED MOTION STUDY.

A Collection of Papers on the Efficient Method to Industrial Preparedness. By Frank B. Gilbreth and L. M. Gilbreth, N. Y., The Macmillan Co., 1919. 220 pp., plates, 1 chart, 8 x 5 in., cloth, $1.50.

This collection describes the application of motion study in various fields of activity and the methods by which it is applied. It also gives the results obtained in various cases and suggests the fields in which it may be used with benefit.

ENGINEERING EDUCATION.

Essays for English selected and edited by Ray Palmer Baker. First edition, N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 185 pp., 8 x 5 in., cloth, $1.25.

CONTENTS: The origins of engineering education. The types of engineering education. The bases of engineering education.

Under these headings the Professor of English in the Rensselaer Polytechnic Institute has grouped fourteen essays, written by prominent American and English engineers during the past decade, which deal with various aspects of engineering education. The book is intended for use in elementary courses in exposition in schools of engineering.

CHILTON AUTOMOBILE DIRECTORY, January 1920.

Published quarterly by the Chilton Co., Phila. 1000 pp., 10 x 6 in., cloth, $5.00.

This quarterly directory of the automobile industry contains a classified list of the American manufacturers of passenger and commercial motor-cars, automobile equipment, parts and machinery for their manufacture. The arrangement is alphabetic and the classification is quite detailed.

In addition, the book contains a directory of automobile trade associations, a table of the serial numbers of American motor cars, the standards of the Society of Automotive Engineers and various engineering tables.

ENGINEERING MACHINE TOOLS AND PROCESSES.

A Text-Book for Engineers, Apprentices, and Students in Technical Institutes, Trade Schools and Continuation Classes. By Arthur G. Robson. Lond. & N. Y., Longmans, Green & Co., 1919. 307 pp., illus., tables, 9 x 6 in., cloth, $4.00.

This work presents a course in the systematic study of machine work and machine tools which is practical rather than theoretical in character. The methods and machines described are those used in British shops and the volume is intended for use in that country.

FATIGUE STUDY.

The Elimination of Humanity's Greatest Unnecessary Waste, a First Step in Motion Study. By Frank B. Gilbreth and Lillian M. Gilbreth. N. Y., The Macmillan Co., 1919. 175 pp., plates, 8 x 5 in., cloth, $1.50.

This book is a study of fatigue in workmen and its prevention. It aims to determine what fatigue results from various types of work and how unnecessary fatigue may be eliminated and necessary fatigue reduced to a minimum. Numerous appliances and methods are described.

HIGHWAY INSPECTOR'S HANDBOOK.

By Prevost Hubbard. First edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 372 pp., 55 illus., diagrams, tables, 7 x 4 in., flexible cloth, $2.50.

The author has endeavored to present most of the important details of highway construction and maintenance, as briefly as possible, in such form as to be quickly available to the inspector, who wishes to be told what to do rather than what others have done under similar circumstances. Considerable explanatory matter has been included and diagrams have been used freely to present data in convenient form for field use. The volume is of convenient size for the pocket.

INORGANIC CHEMICAL SYNONYMS and Other Useful Chemical Data.

By Elton R. Darling. N. Y., D. Van Nostrand Co., 1919 100 pp., 7 x 4 in., cloth, $1.00.

The author has collected the various synonyms that have been used in scientific and trade literature to designate the chemicals in common use and has arranged them so that the substance in question can be accurately identified.

THE LABOR MARKET.

By Don D. Lescohier. N. Y., The Macmillan Co., 1919. 338 pp., 9 charts, 8 x 5 in., cloth, $2.25.

This work is intended for general readers. employers, legislators, employment officials, college teachers and students of the employment and labor problem. The factors of supply and demand, labor market machinery and special employment problems are discussed. The author advocates national control of the problem of employment. An extensive bibliography is included.

MANUFACTURE AND USES OF ALLOY STEELS.

By Henry D. Hibbard. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 14 + 96 pp., 9 x 6 in., cloth, $1.25. (Wiley Engineering Series).

In this monograph, the author has tried to give briefly information of present value relating to the manufacture and uses of the various commercial alloy steels, with the hope of stimulating

the demand for them and extending their practical use. The steels considered are tungsten, chromium, manganese, nickel, silicon, nickel-chromium, chromium-vanadium and high speed tool steels. Bibliographies are given for each.

MUNICIPAL ENGINEERING PRACTISE.

By A. Prescott Folwell. First edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 422 pp., illus., 1 plate, tables, 1 map, 9 x 6 in., cloth, $3.50.

The author of this volume has tried to provide a text-book treating all those matters which enter into the work of a city engineer, with the exception of sewerage, water supply and street paving. City plans, street details, bridges and waterways, city surveying, street lights, signs and numbers, street cleaning and sprinkling, waste disposal, markets, comfort stations, baths, parks, cemeteries and shade trees are discussed at greater or less length.

PARKS AND PARK ENGINEERING.

By William T. Lyle. First edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 130 pp., illus., plates, 1 map, 9 x 6 in., cloth, $1.25.

CONTENTS: Desirability and Acquisition of Parks; Lands and Surveys; Design; Labor and Contracts; Construction.

This book is prepared for the benefit of inexperienced engineers, but will also, the author hopes, be useful to members of newly formed park associations and commissions.

TECHNICAL METHODS OF ORE ANALYSIS.

By Albert H. Low. Eighth edition N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 388 pp., 21 illus., tables, 9 x 6 in., cloth, $3.25.

This manual is intended primarily for the technical chemist, for whom it provides a collection of tested short technical methods adapted to the cases most likely to be met in practise, described with minute detail. The present edition has been thoroughly revised and a number of new methods have been added.

EFFICIENT BOILER MANAGEMENT.

With notes on the operation of Reheating Furnaces. By Chas. F. Wade. Lond. & N. Y., Longmans, Green & Co. 1919. 14 + 266 pp., illus., tables, cloth, 9 x 6 in., $4.50.

The author of this work endeavors to explain, in their prope sequence, the elementary scientific principles underlying the various subjects combined in boiler management and the systematic practical application of these principles to obtain the greatest efficiency. The book is intended to fill the gap between the treatises upon the chemistry of combustion, etc., in which practical applications are omitted, and the practical text-books on boiler plants, which give little attention to the fundamental principles governing their operation.

MODERN ROADS.

By H. Percy Boulnois. Lond., Edward Arnold, 1919. 302 pp. 13 plates, figures, charts, tables, 8 x 5 in., cloth, $5.75.

This book is intended as a comprehensive survey of the present status of road construction and maintenance in Great Britain. Water-bound macadam roads, tarred, concrete and bituminous roads and pavements are included, together with chapters on bituminous carpets, waves and corrugations, and slippery streets.

PROSPECTING FOR OIL AND GAS.

By L. S. Panyity. 1st edit. N. Y., John Wiley & Sons, Inc., 1920. 249 pp., 128 fig., 28 tables, 8 x 5 in., cloth. $3.25.

This work is written for practical oil men and the general public interested in oil investments. It is intended to provide an account of the tools and methods used by scientific prospectors for oil and gas which will enable those without especial knowledge of geology to realize what may be expected of the geologist, to analyze a geological report and to pass judgment upon its merits. The book is based upon a study of the literature and the practical experience of the author, who is a member of the American Institute of Mining and Metallurgical Engineers.

TIME STUDIES FOR RATE SETTING.

By Dwight V. Merrick, with a foreword by Carl G. Barth. N. Y., The Engineering Magazine Company, 1919. 366 pp., 137 fig., 9 x 6 in., leather.

The author of this work presents in amplified form the principles covering time study for rate setting, describes various mechanisms that have been found helpful in making and using such studies and presents some details of practise. An example of the application of time studies to a line of machine tools is included, together with detailed times for a number of other kinds of work.

PRINTING TRADES BLUE BOOK.

National Edition, 1920. Chicago, edited and published by A. F. Lewis & Co., 287 pp., 8 x 6 in., cloth, $ . .

This directory contains the names and addresses of manufacturers of printers' and bookbinders' supplies and equipment arranged by firm names and lines. It is intended for makers and users of printed matter.

SAFETY FUNDAMENTALS.

Lectures given by Safety Institute of America (Maintaining the American Museum of Safety). N. Y., Safety Institute of America, 1920. 228 pp., Illus., plates, 8 x 5 in., cloth, $2.00.

CONTENTS: The body which gets hurt. The injured body and its treatment. (a) Protective clothing for man. (b) Suitable work garments for women in industry. Safe heads and good eyes. Guarding machinery. Arrangement of machinery and working places. Heating and ventilation. Illumination. Nature's forces for and against workmen. Safety education and shop organization.

These lectures were delivered during 1919 before an audience of factory inspectors employed by the City of New York, the states of New York and New Jersey, and insurance companies in and near New York. They are intended to enlarge the knowledge and increase the experience of inspectors with respect to the various fundamentals that affect the mind and body of the workman.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Boston.—February 24, 1920, Harvard Union, Cambridge, Mass. Informal dinner followed by a talk by Professor George F. Swain on "A National Department of Public Works." This was a joint meeting of The Boston Society of Civil Engineers, The Boston Sections of the A. S. M. E. and A. I. E. E. Attendance 45.

March 2, 1920, M. I. T. Dinner in the Grill Room at the Walker Memorial, M. I. T., followed by a talk by Dr. E. B. Rosa on "The Work of the Bureau of Standards During the War and After." Attendance 70.

Denver.—February 21, 1920, Kenmark Hotel. Business meeting, followed by a talk by Mr. Wilson A. Carter, who gave a very able digest on the Engineering License Laws of the United States and the model laws submitted for consideration to the national Engineering Council by its committee. Very beneficial and instructive discussion was had on this subject, participated in by a representative from the Engineer's Examining Board of the State, Mr. Hosea, and by the State Attorney General, Mr. Keys. Attendance 26.

Indianapolis-Lafayette.—February 20, 1920. Subject: "Present Day Problems in the Electric Railway Field." Speaker: Professor D. D. Ewing, of the Department of Electrical Engineering, Purdue University. The address was followed by a three-reel motion picture showing the development of transportation facilities from the earliest period in American history to the so-called "King of the Rails," the mammoth electric locomotive in use on the Chicago, Milwaukee & St. Paul, Great Northern lines and others whose tracks cross

the Rocky Mountains. In connection with the present day conditions of electric railways, Professor Ewing declared that the question was largely one of lowering operating expenses and that much was being accomplished along that line in smaller cities by the use of the one-man car. Attendance 60.

Lynn.—February 18, 1920, G. E. Hall, W. Lynn. Subject: "Electric Propulsion of Ships." Speaker Mr. Eskil Berg, of the Turbine Engineering Department, G. E. Co., Schenectady, N. Y. Mr. Berg illustrated the lecture by a large number of lantern slides as well as a moving picture film showing the propelling apparatus of the U. S. S. New Mexico. Attendance 250.

Madison.—February 24, 1920, Engineering Bldg., Univ. of Wis. Subject: "Light, A New Call to the Engineer." Speaker: Mr. E. A. Anderson, of Nela Park. Mr. Anderson gave a very interesting talk on the increased efficiency due to good lighting and showed good lighting was a paying proposition. The effect of various reflectors was discussed, and the standard R. L. M. reflector was shown. During the talk a series of slides were used showing the effect poor and good lighting has on making a factory a fit place to work in.

Philadelphia.—March 8, 1920, The Engineers Club. Subject: "Operating Performance of Insulators on a 45,000 volt System." Speaker: Mr. H. B. Vincent, of Day & Zimmerman. A discussion by representatives of operating utilities followed the meeting. Attendance 74.

Pittsfield.—February 5, 1920, Park Club. Subject: "Solar Physics." Speaker: Dr. H. T. Stetson, Cambridge, Mass. Attendance 50.

February 19, 1920, Park Club. Subject: "The Thunder Storm." Speaker: Professor William J. Humphrey, Weather Bureau, Washington, D. C. Attendance 125.

March 4, 1920, Park Club. Subject: "Ten Years in Industrial Lighting." Speaker: Professor C. L. Clewell, University of Pennsylvania. Attendance 125.

Rochester.—February 27, 1920. Subject: "Manufacture of Aluminum." Speaker: Dr. Earl Blough, Head of Research Dept., Aluminum Company of America. Attendance 37.

San Francisco.—February 26, 1920. Subject: "Automatic Railway Sub-Stations." Speaker: Mr. W. P. L'Hommedieu. The talk was illustrated with lantern slides, showing typical apparatus and also diagrams which explained the functioning of the various relays, etc. Attendance 60.

Schenectady.—February 20, 1920, Edison Club Hall. Subject: "The Last Stand of the Reciprocating Steam Engine." Speaker: Mr. A. H. Armstrong, G. E. Co. Mr. Armstrong first showed a number of slides giving data in connection with the operation of railways in the United States in the year 1918. These tables gave the total ton-mile movement, the relation between ton-miles and kw. hours as shown by the various installations from which data has been compiled. He proceeded to point out the total saving in coal both by electrification of certain zones as well as by electrification of the complete systems of the country. Data was presented showing the relative maintenance costs of the different types of electrical equipments now in use in this country and abroad. A comparison was made between these costs and those applying to the steam equipment now in use by various railways. It was pointed out that one of the essential differences in maintenance between steam and electrical equipment is due to the high standby losses of all steam equipment as well as the great amount of time required for overhauling and repairs. Attendance 230.

March 5, 1920, Edison Club Hall. Subject: "Flywheel Effect for Synchronous Motors Connected to Reciprocating Compressors." Speaker: Mr. R. E. Doherty, G. E. Co. Mr. Doherty outlines briefly the history of the application of synchronous motors to various types of mechanical loads. By means of a diagram the effect of a variable force and a constant force on a given load were shown. Starting with a simple case there was shown a method of determining the average force, and from this determination were obtained successively the values of velocity and displacement. After outlining the method a specific problem was taken and the method of calculating the different forces involved in the reciprocating unit, starting with the crank effort diagram. The method of analyzing this crank effort by a curve was shown and its use in the design of the complete unit shown. By further illustration it was shown that an extreme condition of hunting could be improved both by the addition and removal of flywheel effect. However, this same illustration proved that all of the conditions must be taken into consideration in order to obtain the proper flywheel effect for successful operation. Attendance 90.

Seattle.—February 17, 1920, Artic Club Assembly. Business meeting followed by a talk on "Electricity in Pierce County Coal Mines" by Mr. E. J. Barry, of Tacoma. The general problems involved in the installation and operation of electrical equipment in and around a coal mine were discussed and the installation of an armored cable in the Wilkenson Mine was described in detail. Attendance 45.

Toronto.—February 20, 1920, Engineers' Club. Subject: "Ice Ages and their Causes." Speaker: Dr. A. P. Coleman. The speaker described various theories as to the causes of the several ice ages, and by means of a considerable number of lantern slides showed the evidence of the Ice Ages that is available at the present day. Attendance 54.

Washington.—March 9, 1920, Cosmos Club. Business meeting, followed by an illustrated talk on "Electrolysis" by Mr. E. R. Shepard, of the Bureau of Standards. Attendance 103.

PAST BRANCH MEETINGS

Bucknell University.—March 8, 1920, Chemical Laboratory. An illustrated lecture was given by Mr. G. A. Island, of the Bethlehem Steel Co., on "The Use of Electricity in the Manufacture of Steel." Slides were shown of the different departments with generators, motors and switchboards. Attendance 51.

University of California.—February 11, 1920, Mechanics Building. Subject: "North Fork Power Plant." Speaker: Mr. C. S. King. Attendance 45.

Carnegie Institute of Technology.—February 26, 1920, Machinery Hall. Subject: "Electricity, the Servant of Man in the Home, in the Industries, in Transportation and in Ship Propulsion. Speaker: Mr. M. C. Turpin, W. E. & M. Co. The address was illustrated with about 75 lantern slides showing applications of electricity in many different industries. A number of noteworthy points were discussed and illustrated, among them the latest Turbo-Alternator of 70,000 kv-a. capacity, the Cottrell System of smoke precipitation and electrical ship propulsion. Attendance 100.

Clarkson College of Technology.—March 4, 1920. Social meeting, featuring six reels of films. Attendance 104.

Clemson Agricultural College.—March 2, 1920, E. E. Lecture Room. Subject: "Electric Power Systems of the Southern Appalachian Watershed." Discussion by Messrs. C. L. Shuler, J. W. Allison, A. H. Dula. Also "Life of Franklin" by S. N. Mace, and "Current Events" by A. R. Eppes. Attendance 56.

University of Kentucky.—February 23, 1920, Mechanical Hall. Subjects: "Series Systems for Street Lighting Distribution" (Jan. '20 Journal) C. M. Hargraves; "Starting Conditions of Synchronous Machines" (Jan. '20 Journal) C. W. Gordon; "Multiple System for Street Lighting Distribution" (Jan. '20 Journal) J. S. Misrach; "Measurement of Projectile Velocities" (Feb. '20 Journal) C. R. McClure. Attendance 19.

Massachusetts Institute of Technology.—February 26, 1920, Paper: "Electrical Transmission of Thought and of

Motion." Author: H. S. Osborne, A. T. &. T. Co. Attendance 70.

University of Michigan.—February 19, 1920. Films from electrical concerns were shown showing progress in electrification of railroads. Attendance 55.

School of Engineering of Milwaukee.—February 20, 1920. Two interesting films "The King of the Rails" and "The Benefactor" were shown. Attendance 98.

Montana State College.—February 25, 1920, Physics Lecture Room. Illustrated lecture on "Electrical Ship Propulsion" by Mr. S. Ellefson, G. E. Co. Attendance 59.

North Carolina State College.—February 10, 1920, E. E. Class-Room. Mr. M. L. Matthews read an article from the *Electrical Experimenter* about Mr. Edison. An interesting mock trial was held. Attendance 27.

February 17, 1920, E. E. Class-Room. Business meeting. Attendance 27.

February 24, 1920, E. E. Class-Room. Subject: "Hydroelectric Development." Speaker: T. G. Young. Attendance 26.

University of Notre Dame.—February 2, 1920, Engineering Hall. Subject: "Solution of the Railway Problem" by W. J. Douglass, and "Advantages Offered by the General Electric Company" by James McNulty, of the G. E. Co. Attendance 25.

March 1, 1920, Engineering Hall. Subjects: "Benefits and Impression of the Inspection Tour" by O. E. Ruzek, and "Derivation of Cyanides and Nitrogen Compounds by the Electric Furnace Method" by J. A. Bailey. Attendance 21.

Oklahoma A. & M. College.—February 18, 1920, E. E. Lecture Room. Two papers by students were presented: "Automatic Telephony" by L. L. Coleman, and "Street Lighting" by Edward Sadlo. Attendance 19.

Syracuse University.—February 18, 1920. Subject: "The Electron Theory." Speaker: Mr. B. I. Hayford. Attendance 11.

February 23, 1920. Joint meeting of A. I. E. E. Branch and A. S. M. E. in College of Applied Science. Illustrated lecture by Dr. Cook, of the McIntosh and Seymour Corporation, on Diesel Engines. Attendance 90.

A. & M. College of Texas.—February 23, 1920, E. E. Building. Business meeting; discussion of coming Electrical Show. Attendance 78.

Washington State College.—January 16, 1920, M. A. Building. Election of officers as follows: President, N. E. Lytle; Secretary, C. Kreisher. Subject: "The Future of the Young Engineer." Speaker: Prof. J. A. Ramsey. Attendance 30.

February 27, 1920, M. A. Building. Election of Glen Langdon as President to take place of N. E. Lytle. Subject: "Engineering Research Work at Washington State College." Speaker: Mr. Dana. Attendance 30.

Yale University.—February 24, 1920, Dunham Lab. of E. E. *Afternoon meeting*—Subject: "Illumination and its Relation to the Arts, Sciences and Professions." Speaker: Mr. S. E. Doane, Pres. of Illuminating Engineering Society, and Chief Engineer, National Lamp Works of G. E. Co. Attendance 100.

Evening Meeting—Subject: "Illumination in Industry—Its Relation to Production—The Economical Results." Speaker: Mr. S. E. Doane, Attendance 60.

Drexel Institute.—February 12, 1920, D. C. E. Club Rooms. Subject: "What is the Matter with Engineering?" Speaker: Prof. Disque, head of E. E. Dept. Also general discussion on Radio Telegraphy and possible communication with Mars. Attendance 19.

Michigan Agricultural College.—January 27, 1920, R. E. Old's Hall of Engineering. Mr. R. A. Shenefield presented a paper on the construction of large turbo-alternators and Mr. A. P. Bock gave a paper on Induction Generators. Attendance 16.

February 17, 1920, R. E. Old's Hall of Engineering. Two reels of motion pictures, "Queen of the Waves," were shown. This gave the entire history of water navigation beginning with the Indian's crude paddling on a log and following up to our latest super-dreadnaught which is electrically propelled. Five hundred years progress shown in thirty minutes. The pictures were supplemented by an interesting talk by Professor M. M. Cory. Attendance 77.

March 3, 1920, Lansing Chamber of Commerce. Banquet and joint meeting with M. A. C. Branch, A. S. M. E. and M. A.C. Chemical Engineering Society, and talks by the following: General Leonard A. Wood "The Engineer in War, and Our Military Policy;" O. C. Echert "Opportunities in Municipal Engineering;" F. F. Rogers "The Highway Engineer;" C. E. Bemet "The Demands of Modern Business." Mr. G. W. Bissell, Dean of Engineering, acted as Toastmaster. Attendance 150.

University of Michigan.—March 11, 1920, Engineering Building. Short business meeting, followed by a talk on "Communication" by Mr. R. S. Parker. Attendance 45.

University of Pennsylvania.—March 1, 1920, Houston Hall. A talk was given by Mr. C. W. Plass on the need of acquaintanceship outside of the engineering field; also talks by C. C. Meyer on "The Development of the Direct Current Motor" and L. O. Tashjian on "The Development of the Induction Motor." Attendance 65.

University of Washington.—March 2, 1920, Forestry Hall. Subject: "Electric Furnaces for Steel Working." Speaker: Mr. John R. King, of the Vulcan Manufacturing Company. Attendance 29.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MARCH 12, 1920

ADAMS, CLAUDE, H., Electrician, with Donahue & Shoebottom; res., 54 Scovill Place, Detroit, Mich.

ADELBERG, I. S., Dist. Manager, Century Electric Co., 506 Rockefeller Bldg., Cleveland, Ohio.

ADMIRE, AMZI ORAL, Experimenter, National Lamp Works, General Electric Co., Nela Park, Cleveland, Ohio.

AHEARN, WILLIAM H., Railway Engineer, with John A. Beeler, 52 Vanderbilt Ave., New York, N. Y.

ANDREWS, JOSEPH F., Telephone Engineering, American Tel. & Tel. Co., 1422 Hurt Bldg., Atlanta, Ga.

ARMSTRONG, CHARLES HENRY, Inspecting Engineer, Georgia Railway & Power Co., Gas & Electric Bldg., Atlanta, Ga.

ARMSTRONG, VERNON D., Asst. Distribution Engineer, Puget Sound Traction, Light & Power Co., 601 Electric Bldg., Seattle, Wash.

AUSTERMILLER, ELMER O., Electrical Engineer, La Belle Iron Works; res., 521 6th Ave., Steubenville, Ohio.

*BACON, MARION F., Commercial Work, Battery Charging Equipment, General Electric Co.; res., 529 W. Washington Blvd., Ft. Wayne, Ind.

BAGBY, C. C., Traffic Engineer, Mountain States Tel. & Tel. Co., 1421 Champa St., Denver, Colo.

*BARNES, SHEPARD, Sales Engineer, General Electric Co., 1100 Electric Bldg., Buffalo, N. Y.

BEACH, SAMUEL W., Office Telegraph Censor, U. S. Railroad Administration; res., 707 20th St. N. W., Washington, D.C.

BEATTIE, WILLIAM P., Engineering, The American Laundry Machinery Co., Norwood, Ohio.

BENZON, AXEL, Chief Engineer Davidson Chemical Co., Curtis Bay, Md.

BERGEGRUN, THEO., Chief Electrician, The Osgood Co., Chief Elect., Comm. Steel Casting Co., Marion; res., Green Camp, Ohio.
BUELHAUSEN, EDGAR, Draftsman, Interborough Rapid Transit Co.; res., 174 Elm St., Yonkers, N. Y.
BEYNER, R. ALVIN, Designing Engineer, District Office, Gen. Elec. Co.; res., 572 Terrace Ave., Clifton, Cincinnati, Ohio.
BIRD, ARTHUR, C., Cadet Engineer, Public Service Electric Co., Newark; res., 88 Meade Ave., Passaic, N. J.
BISER, MARK H., Instructor, Bliss Electrical School, Washington D. C.
*BLANDING, FREEMAN A., Student Engineer, General Electric Co.; res., 1326 State St., Schenectady, N. Y.
*BOICE, WILLIAM B., Student, University of Michigan, Ann Arbor, Mich.; res., 114 23rd St., Toledo, Ohio.
BOWIE, JAMES W., Chief System Operator, New England Power Co., Millbury, Mass.
BRADFIELD, JOSEPH M., Asst. Chief Engineer, Southern Underwriters Association, Atlanta, Ga.
BURGESS, WILLIAM H., General Foreman, Overhead Construction for Elec. Lt. & Pr., Cleveland Elec. Illuminating Co., Cleveland, Ohio.
BURRAGE, CLAUDE, Sales Engineer, Cutler-Hammer Mfg. Co.; res., 146 18th St., Milwaukee, Wis.
BURTZBERGER, FRED, 56 Sulgeneck Strasse, Berne, Switzerland.
CAFFREY, CHARLES S., Asst. Power Engineer, New York & Queens Elec. Light & Power Co., Long Island City, N. Y.
CAMPBELL, JAMES S., Electrician, Paul Whitin Mfg. Co., Northbridge, Mass.
CARSWELL, HOWARD L., Head of Service Dept., Lincoln Electric Co., 3215 Singer Bldg., 149 Broadway, New York, N. Y.
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CHOW, NIEN-TIEN, Graduate Student Apprentice, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
CHRISTIAN, WILLIAM J., Electrician, E. J. Electric Co.; res., 167 West 102nd St., New York, N. Y.
CHURCH, OLIVER A., Electrical Drafting, Lockwood Green Co., 245 State St., Boston, Mass.
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CLARKE, SAMUEL A., Charge of Circuit Breaker & Detail Design Section, Can. Westinghouse Co., Hamilton, Ont.
*COLDWELL, EVERETT S., Industrial Engineer, W. B. Richards & Co.; res., Technology Club, 17 Gramercy Park, New York, N. Y.
COOK, PERCY E., Designing Engineer, Pittsburgh Transformer Co., Pittsburgh; res., 159 Kendall Ave., Bellevue, Pa.
*COSTA, JOSE DE A., 5340 Magnolia Ave., Germantown, Philadelphia, Pa.
CROCKETT, CHARLES N., Chief Electrician, Kingsport Tannery & Extract Corp., Kingsport, Tenn.
CROFOOT, CLARENCE E., Instructor in Electricity, Washington Junior High School, Rochester, N. Y.
CROUCH, ERNEST L., Plant Engineer, The Petroleum Iron Works of Ohio, Sharon, Pa.
DALZELL, DAVID R., Electrical Engineer, General Electric Co., Pittsfield, Mass.
DASCHKE, PAUL ARTHUR, Chief Draftsman, Dictograph Products Corp., Jamaica; res., 174 8th Ave., Astoria, L. I., N.Y.
DAZA, GABRIEL A., Graduate Student, Educational Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
*DEQUINE, GEORGE F., Asst. Gen. Supt., Beloit Water, Gas & Electric Co., Beloit, Wis.
*DODGE, CHESTER C., Testman, General Electric Co.; res., 137 Park Ave., Schenectady, N. Y.
DOLPH, NORMAN L., Engineer, Distribution Engineer's Office, The Detroit Edison Co.; res., 285 Ivanhoe Ave., Detroit, Mich.
DRAKE, RALPH A., Meter Engineer, Turners Falls Power & Electric Co.; res., 237 White St., Springfield, Mass.
*EARLE, RALPH H., Engineer, The Cutler-Hammer Mfg. Co., Milwaukee, Wis.
*EDQUIST, PAUL E., Meter Division, City Light Department; res., 923 E. John St., Seattle, Wash.
EDWARDS, LIONEL G., Superintendent, Hydro-Electric Power Commission, Healey Falls, Ontario.
ELLSWORTH, GEORGE L., Electrician, Substation Operator, So. California Edison Co.; res., 641 East C St., Colton, Cal.
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ENGLISH, MATTHEW R., Electrical Technican, Charles Lentz & Sons; res., 6311 Regent St., Philadelphia, Pa.
ESCHHOLZ, OTTO H., Research Engineer, Materials & Process Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
EVANS, THOMAS MCKINLEY, Transformer Engg. Dept., General Electric Co., Ft. Wayne, Ind.
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FIELDS, ERNEST, Electrician, Union Gas & Electric Co., West End Station, Cincinnati, Ohio.
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FRANKLIN, MARCUS R., Electrical Designer, E. I. du Pont de Nemours Co., Wilmington, Del.; res., 419 Franklin St., Darby, Pa.
FROHMAN, OSCAR, Designer, Electrical Div., B. F. Goodrich Co.; res., 842 Sichley Ave., Akron, Ohio.
FULLER, STEPHEN J., Asst. Inspector of Electrical Material, Elec. Testing Laboratory, Navy Yard, New York, N. Y.
FUNG, WILLIAM WAI, Sales Correspondent, Engineer & Exporter, Westinghouse Electric International Co., E. Pittsburgh, Pa.
GIBARATZ, GEORGE A., Electrician, Michigan Alkali Co. Works 2; res., 373 Third St., Wyandotte, Mich.
GILLIATT, CHARLES F., Supt. of Equipment, Toronto & Niagara Power Co., 150 Fermanagh Ave., Toronto, Ont.
*GORDON, MURRAY L., Commercial Engineering, General Electric Co.; res., 529 W. Washington Blvd., Ft. Wayne, Ind.
GOTTO, ANTHONY J., Tester, Crocker-Wheeler Co., Ampere; res., 211-213 Summer Ave., Newark, N. J.
GOULD, WILLIAM S., Electrical Engineer, with John A. Stevens, 8 Merrimack St., Lowell, Mass.; res., Nashua, N. H.
GOURDON, PAUL E., Draftsman, Chile Exploration Co., 120 Broadway, New York, N. Y.; res., Cranford, N. J.
GRANDY, CHARLES C., Radiologist, Lutheran Hospital, Fort Wayne, Ind.
HAGAN, JAMES S., General Engineer, General Engineering Division, Westinghouse E. & M. Co., East Pittsburgh, Pa.
HAGAR, GEORGE H., Engineer, Vallejo Electric Light & Power Co.; res., 545 Georgia St., Vallejo, Cal.
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HATHAWAY, ERNEST C., Power Engineer, with Nathaniel S. Chase, Bordon Block, Fall River, Mass.
*HAUSER, OSCAR E., Asst. Meter Engineer, The Detroit Edison Co.; res., 1246 W. Philadelphia Ave., Detroit, Mich.
HAWKINS, CRAWFORD B., Office Engineer, Commercial Dept., Alabama Power Co., Birmingham, Ala.
HAYASHI, ICHIRO, Testing Dept., General Electric Co., Schenectady, N. Y.
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HEROD, WILLIAM R., Construction Engg. Dept., General Electric Co., Schenectady, N. Y.
HEINTZEN, HARRY R., Operating Research Bureau, Milwaukee Electric Railway & Light Co.; res., 646½ 35th St., Milwaukee, Wis.
*HERRICK, WILMER J., Engineer in charge of Inventory, Emergency Fleet Corp., Baltimore, Md.; res., 5719 Broomall Ave., Philadelphia, Pa.
HILTON, CLARENCE E., Master Mechanic & Electrical Engineer, Monarch Coal Mining Co., Monarch, Wyoming.
HINCH, EDWARD F., Asst. Engineer, Hydro-Electric Power Commission; res., 127 Delaware Ave., Toronto, Ont.
HOEGEN, Anna C., Technical Asst., Electrical Testing Laboratories; res., 123 West 40th St., New York, N. Y.
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HOFFMAN, A. J., Electrical Engineer, Lockwood, Greene & Co.; res., 196 Fowler St., Chicago, Ill.
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HUGHES, JAMES M., Testing Dept., General Electric Co.; res., 26 Jay St., Schenectady, N. Y.
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IDELSON, MICHAEL N., Laboratory Engineer, Crocker-Wheeler Co., Ampere; res., 44 N. 17th St., E. Orange, N. J.
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KENWARD ERNEST Supervisor of Telegraphs, Canadian National Railways; res., 224 Fulton Ave., Toronto, Ont.
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MOORE, HARRY HILL, Assoc. Physicist, Bureau of Standards; res., 718 Rock Creek Church Road, Washington, D. C.
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*NORTON, PAUL T., JR., Sales Manager, The Case Crane & Engineering Co.; res., 56 S. 18th St., Columbus, Ohio.
NOTTORF, WILLIAM E. A., Maintenance Superintendent, Kansas City Telephone Co., Kansas City, Mo.
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*OSBORN, BURR K., Milton E. Osborn Co., 715 First National Bank Bldg., Ann Arbor, Mich.
*OWLER, DUNCAN S., Asst. Supt., Fall River Electric Light Co.; res., 870 President Ave., Fall River, Mass.
*PACKER, ALFRED H., Instructor, Ambu Engineering Institute res., 453 W. 61st St., Chicago, Ill.
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PARKER, CARLETON H., Railway Draftsman, Seattle Municipal Street Railway; res., 165 Boston St., Seattle, Wash.
PECK, WARREN O., Superintendent Board of Water Commissioners; res., 120 Robin St., Dunkirk, N. Y.
PEEL, EDWARD R., Sales Representative, Central Electric Company, Chicago, Ill.; res., Davenport, Iowa
PENGELLEY, WALTER G., Sales Engineer, Canadian Westinghouse Co.; res., 50 Gormley Ave., Toronto, Ont.
PENMAN, ROY F., Test Man, General Electric Co.; res., 707 South Ave., Schenectady, N. Y.
PERRY, IRVING D., Electrician, Public Service Electric Co., Newark; res., 68 N. Parkway, East Orange, N. J.
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PHILBRICK, FREDERICK B., Instructor in Electrical Engineering, Mass. Inst. of Technology, Cambridge; res., 175 Main St., Winthrop, Mass.
PLAYFORD, Everard W., Dist. Engineer, Canadian General Electric Co., Montreal, Quebec.
POOLE, WILLIAM E., Inside Wireman, for L. K. Comstock Co., 21 E. 40th St., New York; res., 2901 W. 8th St., Brooklyn, N. Y.
RADER, RAY, Engineering Clerk, Puget Sound Traction, Light & Power Co., 605 Electric Bldg., Seattle, Wash.
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ROGERS, EMERSON B., Westboro, Mass.
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RYAN, FRANCIS J., Computer, Corporation Engineering Dept., Illinois Central R. R., Chicago, Ill.
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SEYFORTH, OTTO K., Supt., Western Division, Alabama Power Co., Birmingham, Ala.

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SHOEMAKER, MAYNARD P., Associate Physicist, Bureau of Standards, Washington, D. C.
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SMITH, A. L., SUPT., Electrical Construction, Georgia Railway & Power Co., Atlanta, Ga.
SMITH, CHARLES G., Research Engineer, American Radio & Research Corp., Medford Hillside; res., 1137 Mass. Ave., Cambridge, Mass.
SMITH, CHARLES L., Transformer Sales Dept., General Electric Co., Pittsfield, Mass.
SMITH, FRANK P., Electrical Engineer, Mora & Mendosa, 111 Broadway, New York; res., 364 Grand Ave., Brooklyn, N. Y.
*SMITH, HUGH A., Valuation Dept., Idaho Power Company, Boise, Idaho.
SNYDER, GEORGE R., Chief Electrician, E. & G. Brooke Iron Co., Birdsboro; res., Douglassville, Pa.
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THOMPSON, HOWARD A., General Engineering Dept., Westinghouse Elec. & Mfg. Co.; res., 340 S. Atlantic Ave., Pittsburgh, Pa.
TILLETTE, HUGH A., Engineer, General Electric Co.; res., 60 Livingstone Ave., Pittsfield, Mass.
TITCOMB, LEE R., Asst. Supt., Industrial Laboratory, Klaxon Co., 194 Emmett St., Newark, N. J.
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VAN HORNE, JOHN W., Demonstrator of Electric Welding, Lincoln Electric Co.; res., 8809 Meridian Ave., Cleveland, Ohio.
VAN RAALTE, ARNOLD B., Valuation Inspector, Western Union Tel. Co., 302 Broadway, New York; res., 315 New York Ave., Brooklyn, N. Y.
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VAN VEEN, JOHN, Electrical Construction Foreman, United Gas & Electric Co., Cincinnati, Ohio.
*VICTORY, THORNTON M., Transformer Engg. Dept., General Electric Co., Pittsfield, Mass.
VROOMAN, E. CLIFTON, Engineer, Industrial Control Dept., General Electric Co.; res., 207 Union St., Schenectady, N. Y.
WARFIELD, G. A., Electrical Engineer, General Electric Co.; res., 1226 State St., Schenectady, N. Y.
*WARNER, EARLE E., Engineer, Power & Mining Engg. Dept., General Electric Co., Schenectady, N. Y.
*WARNER, WILBUR W., Farm Light Dept., General Electric Co.; res., 723 Walnut St., Ft. Wayne, Ind.
WARRICK, FRED W. JR., Electrical Draftsman, Philadelphia Rapid Transit Co.; res., 4009 Old York Road, Philadelphia, Pa.
*WEBER, GEORGE E., JR., Salesman, Atlanta Dist., Westinghouse Elec. & Mfg. Co., 1330 Candler Bldg., Atlanta, Ga.
*WEYL, CHARLES N., Engineer, Pioneer Suspender Co., 315 N. 12th St., Philadelphia, Pa.
WHITMORE, LEE E., Chief Test Board Man, American Tel. & Tel. Co., 301 Telephone Bldg., Nashville, Tenn.
WILDBERGER, EARNEST H., Engineering Dept., Georgia Railway & Power Co.; res., 133 East Ave., Atlanta, Ga.
WILSON, ALVIN CHESLEY, Electrical Engineer, Operating Dept., Penn. Water & Power Co., 1611 Lexington Bldg., Baltimore, Md.
WIRTH, GEORGE H., Drafting & Designing, Electrical Work, Stone & Webster, 916 Chestnut St., Philadelphia, Pa.
*WOODSON, J. CLAY, Asst. Inspector of Engineering Material, U. S. Navy, at Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
WOOLFOLK, ARTHUR R., Jr., Patent Attorney, 78 Loan & Trust Bldg., Milwaukee, Wis.
WRIGHT, CHARLES ROY, Engineer, Acme Electric Co., 627 S. Gay St., Knoxville, Tenn.
YAMAOTO, KIYOSHO, Electrical Engineer, Sumitomo Electric Wire & Cable Works, Osaka, Japan.

Total 222
*Former enrolled student.

ASSOCIATES REELECTED MARCH 12, 1920

CANADA, WILLIAM J., Electrical Engineer, Stone & Webster, 147 Milk St., Boston, Mass.
KNAPP, LELAND G., Member of Firm, Goodwin & Knapp, 324 So. La Salle St., Chicago, Ill.
SCHLUSS, K. C., Puget Sound Traction, Light & Power Co.; res., 318 North J St., Tacoma, Wash.
STANFORD, FRED CLINTON, Chief Electrician, Cleveland Cliffs Iron Co.; res., 168 Davis St., Ishpeming, Mich.
WILLS, HARRY L., Engineer & Operating Manager, Georgia Railway & Power Co., Atlanta, Ga.

MEMBERS ELECTED MARCH 12, 1920

*ARNOLD, RUSSELL B., Asst. Signal Engineer, C. & N. W. R. R.; res., 5702 Washington Blvd., Chicago, Ill
BYRD, ALFRED S., Supt. of Power Plants, Montreal Tramways Co., 78 Craig St. West, Montreal, Que.
CAUDRELIER, ETIENNE, Chief Engineer of the Compagnie Parisienne de Distribution d' Electricite; res., 11 rue de Milan, Paris, France.
*COOK, JOEL R., Chief Engineer, Domestic Electric Co., Cleveland, Ohio.
DAVENPORT, FRANK B., Asst. to Electrical Engineer, Georgia Railway & Power Co.; res., 245 E. Pine St., Atlanta, Ga.
DISQUE, ROBERT C., Prof. of Electrical Engineering, Drexel Institute, Philadelphia, Pa.
EDGCUMBE, KENELM, Major, Chairman, Everett, Edgcumbe & Co. Ltd., Collingdale Works, London, N. W. 9, England.
ERICKSON, ROBERT Wm., Chief Electrical Draftsman, Federal Shipbuilding Co., Kearny, N. J.
GOKHALE, SHANKAR L. Magnetic Engineer, General Engg., Laboratory, General Electric Co.; res., 220 Liberty St. Schenectady, N. Y.
*HOPKINS, WARREN B., Acting Electrical Engineer, Stone & Webster, 147 Milk St., Boston, Mass.
MERCIER, ERNEST F. H., Administrateur delegue d l'Union d' Electricite, 57 rue Pierre Charron, Paris, France
PRIESS, WILLIAM H., Chief Engineer, Wireless Specialty Apparatus Co., C & Fargo Streets, Boston, Mass.
ROBINSON, SAMUEL M., Commander, U. S. N., Fleet Engineer; U. S. S. New Mexico, San Francisco, Cal.
TURNER, HUBERT M., Asst. Professor of Electrical Engineering, Yale University, 10 Hillhouse Ave., New Haven, Conn.
WATTS, LEVI, Jr., Sales Engineer, Westinghouse Elec. & Mfg. Co., Boston; res., 55 Wildwood Ave., Arlington, Mass.

FELLOW ELECTED MARCH 12, 1920

NASH, GEORGE HOWARD, Chief Engineer, Western Electric Co. Ltd., Norfolk House, Embankment, London, England.

TRANSFERRED MARCH 12, 1920

To Grade of Member

BEARDSLEY, CLIFFORD R., Electrical Engineer, Fred T. Ley & Co. Inc., Springfield, Mass.
CARROLL, RANDOLPH S., Superintendent, Underground Dept., Portland Railway, Light & Power Co., Portland, Ore.
DUBSKY, FRANCIS, Electrical Engineer, Transformer Engineering Dept., General Electric Co., Pittsfield, Mass.
ELDREDGE, MARK, Engineer, Ludlow Manufacturing Associates, Calcutta, India.
FOSTER, BENJAMIN P., Electrical Engineer, E. I. Du Pont de Nemours & Co., Wilmington, Del.
HESTON, WALTER C., Industrial Power Engineer, Portland Railway, Light & Power Co., Portland, Ore.
HUNT, RAYMOND, General Manager, Tide Water Power Co., Wilmington, N. C.
LINCOLN, JAMES F., General Manager, Lincoln Electric Co., Cleveland, O.
MORTON, ROBERT B., Electrical Engineer, Toltz King & Day, St. Paul, Minn.
NAMBA, MASASHI, Professor of Electrical Engineering, Imperia University, Kioto, Japan.
SCHIPPEL, HENRY F., Research Engineer, Ames Holden McCready, Ltd., Montreal, Que.

SOLOMON, NATHAN C., Contracting Electrical Engineer, New York, N. Y.

STRAW, JESSE B., Chief Engineer, The William Gordon Corp. Philadelphia, Pa.

WISEMAN, ROBERT J., Wire and Cable Engineer, National Conduit & Cable Co., Inc., Hastings-on-Hudson, N. Y.

To Grade of Fellow

GOLDSMITH, ALFRED N., Professor in Charge of Electrical Engineering, College of the City of New York, New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at a meeting held March 8, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Membership

ATKINSON, KERR, Engineer, with Roderick D. Donaldson, New York, N. Y.

CANADA, WILLIAM J., Electrical Engineer, Stone & Webster, Boston, Mass.

FAIR, RICHARD H., Outside Plant Engineer, Bell Telephone System, Northwestern Group, Omaha, Neb.

HOWLAND, RALPH B., Assistant Electrical Engineer, Dwight P. Robinson & Co. Inc., New York, N. Y.

IVES, JOHN NASH, Electrical Engineer, Lockwood, Greene & Co., Boston, Mass.

McEACHRON, KARL B., Research Assistant, Engineering Experiment Station, Purdue University, Lafayette, Ind.

REGAL, A. P., Electrical Engineer, Philadelphia Rubber Works Co., Akron, O.

SCHLUSS, KURT C., Supt. of Power & Equipment, Tacoma Ry. & Power Co., Puget Sound Electric Ry., Puget Sound Traction Lt. & Pr. Co. (Tacoma Div.), Tacoma, Wash.

STANFORD, F. C., Chief Electrician, Cleveland Cliffs Iron Co., Ishpeming, Mich.

STELZNER, W. B., Professor of Electrical Engineering, University of Arkansas, Fayetteville, Ark.

THORNTON, FRANK Jr., Chief Engineer, Westinghouse Electric Products Co., Mansfield, O.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1920.

Abbott, Royal W., San Francisco, Cal.
Albrecht, E. Julius, (Member), Chicago, Ill.
Appel, Henry J., New York, New York.
Aslaksen, Einer, New York, N. Y.
Baily, Ben P., Astoria, Oregon.
Balch, Cleon F., Milwaukee, Wis.
Barnes, Edwin H., Philadelphia, Pa.
Batt, Charles G., Bingham Canyon, Utah.
Beacock, Victor A., Toronto, Ont.
Beatty, Elwood C., (Member), Ampere, N. J.
Beckett, William, (Member), Atlanta, Ga.
Beechinor, Herbert M., New York, N. Y.
Bemis, Edwin W., Worcester, Mass.
Benedict, Roy P., Chicopee, Massachusetts.
Birkinbine, Olaf W., Philadelphia, Pa.
Bischoff, Louis G., Chicago, Ill.
Bissett, John W., New York, N. Y.
Bloch, S., Schenectady, N. Y
Bohmann, Robert B., Milwaukee, Wis.
Bolen, Charles A., Greensburg, Pa.
Bolton, Robert A., Kingston, Ontario
Bordeaux, Ephriam P., New York, N. Y.
Boss, Earle, B., W. Lynn, Massachusetts.
Boutwell, Willard S., Seattle, Washington.
Bowler, William E., Worcester, Mass.
Bowman, Edward C., (Member), New York, N. Y.
Bridges, J. Earle, Jackson, Mich.
Brodsky, Vladimir P., E. Pittsburgh, Pa.
Brown, Harrison G., Portsmouth, New Hampshire.
Brown, Richard, Worcester, Mass.
Bugbee, Ralph L., Boston, Mass.
Burger, Edward J., (Member), Lorain, Ohio
Burman, Charles F., Milwaukee, Wisconsin.
Butler, W. H., Philadelphia, Pa.
Buxton, Vernon R., Boston, Mass.
Calligheris, John S., E. Pittsburgh, Pa.
Carpe, Allen, New York, N. Y
Church, Robert A., New York, New York.
Cigrange, Joseph, Baltimore, Massachusetts.
Clapp, Robert H., New York, New York.
Clark, John A., (Member), Pittsburgh, Pa.
Cox, Robert W. S., Boston, Mass.
Cross, Raymond J., Hoboken, N. J.
Creim, Benjamin W., Los Angeles, Cal.
Daunt, Charles A., S. Boston, Massachusetts.
Davis, Carlos, Glens Falls, N. Y.
Debman, Eugene E., New York, New York
Dee, Thomas C., Ames, Iowa
d'Humy, Fernand E., New York, New York.
Denny, Robert C., Fresno, Cal.
Dewey, Stuart J., Cincinnati, Ohio
Dodge, Harry A., (Member), New York, N. Y.
Duff, John E., Chicago, Illinois.
Dupre, Valentine H., Chicago, Ill.
Eaton, Frederick W., Akron, Ohio
Edmonds, Montrose, Baltimore, Md.
Elliott, James P., (Member), Milwaukee, Wis.
Elstun, William P., New York, New York
Emerson, Cherry L., (Member), Atlanta, Ga.
Fay, Carl J., Mansfield, Ohio.
Ferguson, Alan H., Chicago, Ill.
Fisher, Merdaunt J. M., E. Pittsburgh, Pa.
Flaherty, Leonard T., Stellarton, N. S.
Ford, James E., Somerville, Mass.
Foss, Carl E., Chicago, Ill.
Fowler, Herman M., Seattle, Wash.
French, Ralph W., E. Pittsburgh, Pa.
Frick, Clifford H., Hauto, Pa.
Frisbie, Howard L., (Member), Clarkdale, Ariz.
Fry, Howard M., Bethlehem, Pa.
Fryburg, Warren, New York, N. Y.
Fuller, Carl T., (Member), Harrison, N. J.
Fyke, J. Lowell, (Member), W. Allis, Wis.
Gatter, L. Stewart, (Member), New York, N. Y.
Geder, John J., Milwaukee, Wis.
Giesselberg, George H., New York, N. Y.
Gilson, Wesley J., (Member), Calumet, Mich.
Gross, Frank W., Ft. Sam Houston, Texas
Grunfield, Maurice, New York, N. Y.
Grunsky, Clotilde, San Francisco, Cal.
Hall, Theodore, (Member), Brooklyn, N. Y.
Hardy, George M., (Member), Worcester, Mass.
Harris, Leonard F., New York, N. Y.
Harvey, Lloyd B., Portsmouth, N. H.
Hatz, Earl W., Milwaukee, Wis.
Hecht, J. Bernard, St. Paul, Minn.
Heckman, Chester L., Worcester, Mass.
Heffner, Roy E., Ithaca, N. Y.

Henritze, Richard, E. Pittsburgh, Pa.
Hill, Edwin P., Alameda, Cal.
Hodge, Thomas J., Washington, D. C.
Hoey, William B., Philadelphia, Pa.
Hoffman, R. A., Denver, Colo.
Hollenbeck, Charles H., New York, N. Y.
Howell, George E., Portsmouth, N. H.
Hurley, Wallace P., New York, New York.
Husted, Norris C., Pittsburgh, Pa.
Iler, Stanley B., Toronto, Ontario
Ishimaru, Eikichi, Schenectady, N. Y.
James, Herbert H., Scranton, Pa.
Johnson, Clarence C., (Member), New York, N. Y.
Johnson, Earl A., New York, N. Y.
Kalmbach, Maurice F., Milwaukee, Wisconsin.
Kelley, Thomas C., E. Pittsburgh, Pa.
Keyser, William H., Seattle, Wash.
Kidwell, Herbert W., Washington, D. C.
Killam, Lafayette W., New York, New York.
King, Earl B., Indianapolis, Ind.
Kirby, Joseph H., Jackson, Mich.
Kling, Herbert A., New York, N. Y.
Knapp, Carl M., Houston, Texas
Knickerbocker, Walter G., Marysville, Mich.
Landry, Kenneth W., Worcester, Mass.
Lauber, Calvin G., New York, N. Y.
Leite, Arnaldo F., Wilkinsburg, Pa.
Likely, Robert D., Schenectady, New York.
Lindzey, John O., Elizabethport, N. J.
Long, Orville F., Memphis, Tenn.
Loshing, Clement K., Cleveland, Ohio
Lovett, Fremont L., Worcester, Massachusetts.
Lowell, Glen J., Schenectady, New York.
Luichinger, Martin J., Indianapolis, Ind.
Lundell, George A., (Fellow), New York, N. Y.
MacDonald, Kenneth V., Fulton, N. Y.
MacDonald, Martin W., Hagerstown, Md.
Macpherson, Kenneth P., Kingston, Ontario.
Maddux, Frank N., Milwaukee, Wis.
Magee, Frank L., New Haven, Conn.
Magnuson, John M., Worcester, Mass.
Makous, Lawrence, W. Allis, Wis.
Marquis, James B., Norwich, N. Y.
Maryatt, Elmer F., San Francisco, California.
Meyer, C. Perry, St. Louis, Mo.
Meyers, Philip M., Bridgeton, N. J.
Mintzner, Watkins F., Hamilton, Ont.
Morehouse, Aden K., San Francisco, Cal.
Morgan, Frank I., Holtwood, Pa.
Mosman, Charles F., Boston, Mass.
Murray, Marsden C., (Member), Richmond, Va.
Myers, Clyde J., Detroit, Mich.
McCleery, Harold L., E. Pittsburgh, Pa.
McCormick, Fred J., Milwaukee, Wisconsin.
McDonald, James Walter, Newark, N. J.
McDougall, James C., Seattle, Wash.
Miller, Henry J., Chicago, Illinois.
Mitchell, Harold J., New York, New York.
Montgomery, John V., New York, New York.
Mulkey, San F., St. Louis, Missouri.
Nash, Fred H., Bartlesville, Okla.
Nelson, Edward L., New York, N. Y.
Newton, William J., Bridgeport, Conn.
Noppel, Edward P., Philadelphia, Pa.
Norcross, Josiah C., Boston, Mass.
Nye, Henry V., W. Allis, Wis.
Nye, Irvin W., Nazareth, Pa.
O'Dea, Mathew F., Boston, Mass.
Oldham, Joseph K., Worcester, Massachusetts.
Owen, Ralph J., Milwaukee, Wis.
Parker, Harry C., Toronto, Ont.
Parkerson, Louis R., Long Branch, N. J.
Payne, Edward B., New York, N. Y.
Pearson, H. J. Cory, (Member), Atlanta, Ga.
Penn, Marion, Newark, N. J.
Percival, Harry S., (Member), New York, New York.
Pero, Bertram S., Schenectady, N. Y.
Piper, Carl W., (Member), Lafayette, Ind.
Poupart, Ernest, (Member), Kirkland Lake, Ont.
Pride, Alfred W., Toledo, Ohio
Puchstein, Albert F., Columbus, Ohio.
Reading, Robert S., Houston, Texas
Reynolds, Henry C., Mobile Ala.
Ricciardi, Salvatore, Philadelphia, Pa.
Robinson, Gilbert, Boston, Massachusetts.
Roe, Arthur C., New York, New York.
Rosen, Nathan, Portsmouth, N. H.
Ross, Harold D., Pittsfield, Mass.
Ross, Lindsley W., Portland, Ore.
Rothschild, Harold L., St. Paul, Minn.
Rushton, Frederick, Toronto, Ont.
Sandt, Robert A., (Member), New York, N. Y.
Schnaubelt, Frank J., (Member), Chicago, Ill.
Schulte, Theodore, Calgary, Alta., Canada
Scott, Bernard W., Boston, Mass.
Seabra, Jose R., E. Pittsburgh, Pa.
Shaw, J. B., Greensburg, Pa.
Simmons, Moses H., Franklin, N. J.
Singh, C., Stockton, Cal.
Smith, Charles D., S. Windham, Maine
Smith, Charles G., W. Tulsa, Okla.
Smith, Don F., San Francisco, Cal.
Smith. Glen H., Seattle, Wash.
Smith, Marvin W., E. Pittsburgh, Pa.
Snow, Arthur F., Worcester, Mass.
Snow, Harold M., Dillon, Mont.
Spencer, Frederick A., Northfield, Vermont
Stracham, Harley A., St. Louis, Mo.
Stevens, Vergil, St. Paul, Minn.
Stubinger, Eugene McA., Atlanta, Ga.
Sullivan, M. E., Chicago, Ill.
Sutherland, George (Member), Boston, Mass.
Swann, Edwin H., Philadelphia, Pa.
Swicker, Lester C., New York, N. Y.
Temme, Alfred M., New York, New York.
Thayer, Charles H., Worcester, Mass.
Trompen, Nicholas J., (Member), Brooklyn, N. Y.
Thompson, Theo W., (Member), W. Allis, Wis.
Tischler, Napoleon, New York, New York.
Torrens, Robert J., Washington, D. C.
Townsend, Herbert K., Oakland, Cal.
Transtron, Henry L., Washington, D. C.
Tufty, Harold G., Madison, Wis.
Tyzzer, Howard J., Medford Hillside, Mass.
Underhill, J. Delmar, Passaic, N. J.
Upson, Clair P., Birmingham, Ala.
Van Dorn, Alma L. M., Washington, D. C.
Von Losson, Railey L., Seattle, Washington.
Waters, Basil W., Jr., Hazard, Kentucky.
Wells, Clarence A., San Francisco, Cal.
West, Austin W., (Member), Atlanta, Ga.
West, Benjamin, Cambridge, Mass.
Weyman, Hugh E., (Member), Levis, P. Q.
Whitaker, Edward R., St. Louis, Mo.
White, Daniel W., W. Lynn, Mass.
Whitney, William G., New York, N. Y.
Widmark, Lawrence E., (Member), Newark, N. J.
Wilmeth, Roscoe, St. Marys, Pa.

Wilkinson, Winfred D., Worcester, Mass.
Winter, Boyd W., Seattle, Washington.
Withington, Sidney, (Fellow), New Haven, Conn.
Wood, Raymond, St. Louis, Mo.
Wright, Virn J., Portsmouth, New Hampshire
Wyman, Hugh K., Toronto, Ont.
Yerbury, Charles W., Newark, New Jersey.
Young, A. R., Portsmouth, N. H.
Young, Charles S., Allentown, Pa.
Young, Chi-wei, Milwaukee, Wis.
Young, Warren G., Pittsfield, Mass.
Zimmermann, Arnold, Chicago, Ill.
Zundel, Andrew H., New York, New York.
Total 239.

Foreign

Carter, Thomas, (Fellow), Newcastle-on-Tyne, Eng.
Herzfeld, Raul, Buenos Aires, Argentine.
Heal, Frederick H., Rio de Janeiro, Brazil, S. A.
Hughes, Aubrey E., (Member), Ipswich, Eng.
Reed, Myron G., Irapuato, Gto., Mexico
Sato, Masashi, Shinyanagi-Machi, Nakaku, Nagoya, Japan
Seckman, John R., Santiago, Chile

STUDENTS ENROLLED
MARCH 12, 1920

11209 Worthley, Charles B., University of Washington
11210 Demuth, Orin A., University of Washington
11211 Hayden, Henry T., Jr., University of Washington
11212 Swartwood, Gale K., Iowa State College
11213 Crawford, Charles C., Iowa State College
11214 Hooke, Robert G., Harvard Engineering School
11215 Stavoli, Francisco J.,Escula Practica de Ing. Mecs.y Elec.
11216 Ekeroth, Walter M., Brooklyn Polytechnic Inst.
11217 Pirrone, Peter, Brooklyn Polytechnic Inst.
11218 Tuthill, Bruce C., Brooklyn Polytechnic Inst.
11219 Gildersleeve, Gordon H., Lehigh University
11220 Nordstrom, Carl E., Iowa State College
11221 Berg, Harry A., Iowa State College
11222 Salter, Ernest H., John Hopkins University
11223 Burch, James S., Jr., Trinity College
11224 Cottrell, Camille J., University of California
11225 Colonna, Joseph E., Carnegie Institute of Technology
11226 Cleary, Harold F., University of Minnesota
11227 Jules, Harold A., University of Minnesota
11228 Sweet, Ray P., University of Minnesota
11229 Welsh, Harvey A., University of Minnesota
11230 Magnuson, John E., University of Minnesota
11231 Price, Clarence R., University of Minnesota
11232 Olson, Sigfred G., Oregon State Agr. College
11233 Legg, Aubrey S., A. & M. College of Texas
11234 Zeunert, Eugene H., School of Engg. of Milwaukee
11235 Paustian, Oscar A., School of Engg. of Milwaukee
11236 Drum, George F., Ohio State University
11237 Phillips, Harley, Ohio State University
11238 Roebuck, J. Howe, Ohio State University
11239 Ervin, Kenneth L., Ohio State University
11240 Hoffman, Dan L., Ohio State University
11241 Hoover, Charles H., Ohio State University
11242 Miller, Dale O., Ohio State University
11243 Pepper, Herbert C., Ohio State University
11244 Terry, Donald M., Ohio State University
11245 Baughman, George W., Ohio State University
11246 Boerner, Carl, A. & M. College of Texas
11247 Wells, Cecil G., Oklahoma A. & M. College
11248 Calmus, Clarence J., Iowa State College
11249 Willby, Norman H., Worcester Polytechnic Ins.
11250 Joscelyn, Edwin C., N. Y. Electrical School
11251 Fisher, William S., Syracuse University
11252 Thompson, Amon G., University of Illinois
11253 Avery, Norman K., University of Wisconsin
11254 Bryant, Roger H., Worcester Polytechnic Institute
11255 Johnson, Selmer, Iowa State College
11256 Mansk, Raymond E., Case School of Applied Science
11257 McKee, Edd R., Iowa State College
11258 Lindmiller, Robert P., Case School of Applied Science
11259 Inkley, Edwin A., Case School of Applied Science
11260 Pancoast, Donald F., Case School of Applied Science
11261 Gillmore, Willard F., Case School of Applied Science
11262 Beyer, Claude F., Iowa State College
11263 Hoke, Frank, Swarthmore College
11264 Powell, George A., Swarthmore College
11265 Jones, Russell N., Carnegie Institute of Technology
11266 Burns, Warren W., Iowa State College
11267 Panter, John S., University of Toronto
11268 Hartnett, Frank S., New York Electrical School
11269 Hales, Miles, University of Utah
11270 Carroll, Joseph S., University of Utah
11271 Wilson, Arthur S., University of Toronto
11272 Reinhard, George A., Jr., Catholic Univ. of America
11273 Kist, Carl F., Jr., Catholic Univ. of America
11274 Beck, Ellwood W., Carnegie Inst. of Technology
11275 Knaell, Kenneth K., Carnegie Inst. of Technology
11276 Snider, W. Herbert, University of Wisconsin
11277 Kauffman, Paul E., Y. M. C. A. School
11278 Satori, Roy H., University of Minnesota
11279 Freehauf, Harvey G., University of Minnesota
11280 Overstreet, Frank A., University of New Mexico
11281 Forrest, Henry C., University of Virginia
Total 73

OFFICERS of A. I. E. E. 1919-1920

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(Term Expires July 31, 1920)
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JUNIOR PAST-PRESIDENTS.

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(Terms expire July 31, 1920)
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JOHN B. FISKEN, WILLS MACLACHLAN

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(Terms Expire July 31, 1922) WALTER I. SLICHTER, G. FACCIOLI, FRANK D. NEWBURY
(Terms Expire July 31, 1923) L. E. IMLAY, F. F. FOWLE, L. F. MOREHOUSE

TREASURER **SECRETARY**
(Term expires July 31, 1920)
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RALPH W. POPE

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52 Broadway, New York.

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*FRANKLIN L. POPE, 1886-7.
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*WILLIAM A. ANTHONY, 1890-91.
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FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-9.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK, 1916-17.
E. W. RICE, JR., 1917-18.
COMFORT A. ADAMS, 1918-19.

***Deceased.**

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Chairman of Committee on Technical Activities, the chairmen of all technical committees, and the chairmen of all Sections.

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C. Francis Harding, Vice-Chairman, Purdue University, Lafayette, Ind.
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and the chairmen of all Institute Sections *ex-officio.*

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Charles F. Scott.

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G. E. Stoltz,
and the Chairmen of all Membership Committees of Sections.

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H. W. Buck, Chairman, 49 Wall St., New York.
C. A. Adams, N. A. Carle, John W. Lieb,
A. C. Marshall, Wm. McClellan, C. E. Skinner.

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The Corona Voltmeter and the Electric Strength of Air

A Natural Secondary Standard of Voltage

BY J. B. WHITEHEAD

Professor of Electrical Engineering, John Hopkins University

AND

T. ISSHIKI

Engineer, Shibaura Engineering Works

An improved form of the corona voltmeter is described. Precision measurements of crest values of high alternating voltage taken in the high-tension circuit are compared with the indications of the corona voltmeter.

The law of corona has been determined to a higher degree of accuracy, and a modification in the form of the law as heretofore accepted is revealed.

As based on the precision voltage measurements the corona voltmeter is proposed as a natural secondary standard of high voltages. Its advantages as a standard, and its practical operation are described.

I. Introduction

THE corona voltmeter is an instrument for measuring accurately the crest values of high alternating voltages. It makes use of the fact that corona forms on a clean round wire in air at a sharply marked definite value of voltage dependent in a simple relation on the density of the air. The range of the instrument using a single wire is extended to wide limits by enclosing the wire and varying the density of the air.

The essential elements of the instrument are a central rod or wire on which corona forms, an outer concentric cylinder forming the opposite terminal, an outer air-tight containing case in which the air pressure may be varied, and convenient means for determining accurately the first appearance of corona. The principle and method of operation, including the use of gaseous ionization and sound as corona indicators, and two earlier forms of the instrument have been described in an earlier paper.[1] An improved type of the instrument for voltages in the neighborhood of 150,000 volts is described below and shown in Figs. 9 and 10.

The principal object of this paper is to describe a series of experiments in which the values of corona forming crest voltages have been determined by precision measurements made in the high-voltage circuit. Also to show that the law followed is so definite, and the indications of the instrument so constant, that it constitutes not only an accurate measuring instrument, but also through the results of the present investigation, a natural secondary standard of high voltage possessing many advantages over others at present in use.

An important result of the work is the discovery of an interesting modification of the law of corona formation.

The various precautionary and check measurements staken to ensure the accuracy of the final readings con titute in themselves prime evidence of the accuracy of the corona as a measure of voltage, and also of its constancy and reliability in operation in the corona voltmeter. In addition some further notes on the operation of the voltmeter are given towards the end of the paper.

II. The Corona as a Standard of Voltage

Two striking properties of the high-voltage corona in air have led to the suggestion of its use for the measurement of voltage and to the development of the corona voltmeter. The first is the remarkable constancy of the value of voltage at which, under fixed conditions, the corona appears on a round wire or rod; and the second is the simplicity of the law connecting the critical or corona-forming voltage with the diameter of the rod and the condition of the surrounding gas.

The former of these properties has been noted by a number of observers and in particular by one of the present authors in the first of a series of papers on the electric strength of air,[2] and again especially in a paper on the corona voltmeter.[1] Using a clean round rod and the best type of portable voltmeter in the low-tension circuit, on repeated raising and lowering of the voltage corona appears sharply at exactly the same value throughout, that is, at a value constant to within say one-tenth or one-quarter per cent. Under more refined conditions the constancy is shown to be even closer.

The empirical law connecting the critical or corona-forming voltage gradient E in kilovolts per cm., at the surface of the wire, the radius of the wire r in centimeters, and the relative density of the gas δ, is usually stated in the form

$$E = A\,\delta\left(1 + \frac{B}{\sqrt{\delta\, r}}\right) \qquad (1)$$

A more convenient form for our present purposes is

$$E/\delta = A + \frac{B'}{\sqrt{\delta\, r}} \qquad (2)$$

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1. A bilbiography of all references will be found at the end of the paper.

which gives a linear relation between E/δ and $\frac{1}{\sqrt{\delta\, r}}$; obviously $B' = A\, B$.

The value of δ is given by

$$\frac{3.92\, p}{273 + t} \tag{3}$$

in which p is the pressure in centimeters of mercury and t is the temperature in degrees centigrade.

The above relatively simple relations have now been corroborated by a number of observers and with quite close agreement as to the values of A and B. The influence of the diameter of the wire on corona-forming voltage was first emphasized by H. J. Ryan,[3] who was also the first to point out the possibilities of the corona as a voltage indicator. The exact nature of this influence and the presence of the two constants A and B were first shown by one of the present authors.[4] The precise influence of the density of the air was first shown by F. W. Peek, Jr.,[5] in one of the most important contributions yet made to the knowledge of the subject. Moisture in the air has no effect on the critical intensity.[2]

The form of the above law is the same for both continuous voltages and crest values of alternating voltages. With continuous voltage, however, there are appreciable differences in the values of the constants A and B, as between positive and negative corona-forming wire, the form of the law in each case remaining the same.[6] One of the most important results of the present work is the fact that this difference between positive and negative corona is reflected in the alternating corona, and that the law as given by formulas (1) and (2) must be modified. Briefly stated, the modification consists in the use of different values of the constants A and B above and below a definite value of $\frac{1}{\sqrt{\delta\, r}}$, the form of the law, however, remaining the same in each case, as will be seen below.

It has generally been accepted that within the commercial range frequency has no influence on the corona-forming voltage. Observations with the accurate methods use in the experiments show a slight influence of frequency within the range mentioned.

Since corona formation through the constancy of its appearance and the simplicity of its law offers a ready means for the measurement of high voltage, it is important that the constants A and B be determined accurately. When this is once done, such an instrument as the corona voltmeter has a calibration dependent only on its dimensions, and so constitutes a natural secondary standard of voltage.

Nearly all determinations of alternating corona voltages have been based on observations of voltage and crest factor taken in the low-tension circuit, and computed from transformer ratios. As is well known, this method is subject to serious errors on both accounts. If therefore advantage is to be taken of the constancy of corona voltage as a standard and as a method of measurement, it is necessary that the constants A and B be determined by direct measurement in the high-voltage circuit of the crest values of corona voltage, and to a relatively high degree of accuracy in terms of accepted standards. These determinations once made over a sufficiently wide range of values of δ, corona formation, by reason of the simplicity of the relation of formula (1), and its freedom from outside influence, becomes a far more reliable standard than the sphere gap, the potential transformer, or any other standard at present proposed.

III. Precision Measurement of Corona Constants

For the determination of the values of A and B we must (1) measure accurately the crest value of alternating voltage at which corona appears, (2) be able to observe to as small a difference of voltage as possible the first appearance of corona, and (3) measure δ and provide a wide range of its values.

The crest value of voltage (1) may be determined from the average value of the charging current of an air condenser in the high-voltage circuit. This method first used by Chubb and Fortescue,[7] was modified by Whitehead and Gorton,[8] and is now further improved as described below.

For (2) the accurate observation of the first appearance of corona, two methods are used,—(a) the telephone for detecting the sound of the corona, and (b) the galvanometer for detecting the conductivity of the air caused by the corona. Both methods are used in the corona voltmeter and are described in detail in an earlier paper;[1] further observations are reported below. The visibility of corona is neither convenient nor accurate as a means of determining its first appearance.

The corona voltmeter with its air-tight outer casing provides the method (3) for the observation of δ, the relative air density, and its variation over a wide range. Pressure and temperature are read and the pressure may be adjusted to any chosen value, thus permitting setting for any value of δ.

III. 1. Measurement of Voltage

If an alternating voltage of maximum value E volts and frequency f be impressed on a condenser of capacity C, the average charging current is

$$i = 4\, f\, C\, E; \tag{4}$$

if f and C are known and i is measured E the maximum for the maximum value of charging voltage is determined. When used for the high values of voltage pertaining to corona formation, one side of the condenser is grounded and the charging current measured in the ground connection. Since the condenser must withstand the full maximum voltage and have no dielectric or other loss, the most convenient form is that of concentric cylinders with wide radial separation, and

with air as dielectric. This, however, means small capacity per unit axial length, and small total capacity if the outside dimensions are to be kept within reasonable limits. Consequently the use of this method involves the use of a large air condenser of small capacity and a determination of the value of the capacity.

Chubb and Fortescue[7] constructed a cylindrical condenser consisting of two wooden forms, each covered with sheet metal surfaces. The diameters of the two members were 60 cm. and 162.8 cm. respectively, and the outer member was provided with two flaring guard ring ends. The capacity between the inner member and the central section of the outer member was calculated as 2.65×10^{-11} farad, no attempt at measurement being made, doubtless owing to the difficulty of measuring so small a value. Chubb and Fortescue measured the charging current in the ground connection of the central section of the outer member of the condenser by means of a d'Arsonval galvanometer and a synchronous commutator connected as a shunt suppressor.

In the present experiments the same type of condenser is used, *i. e.*, the cylindrical guard ring type with voltage applied to the inside member and charging current measured in the ground connection of the central section of the outside member. The capacity, however, was measured, as described below. Further, the charging current was measured by the use of two rectifying kenotrons, thus obviating the irregularities and uncertainties of the synchronous commutator. The commutator was, however, frequently used for comparison and certain auxiliary tests.

A diagram of the principal connections is shown in Fig. 1. Voltage is applied from the transformer A to

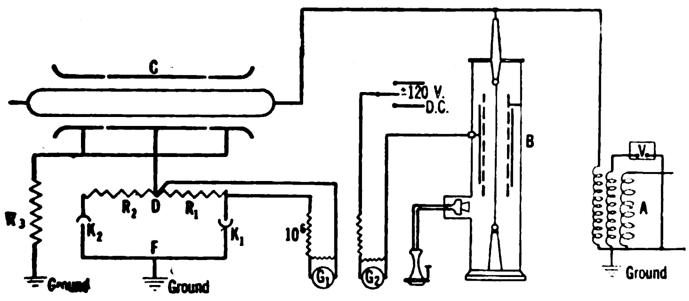

FIG. 1—PRINCIPAL CONNECTIONS

the corona voltmeter B and the air condenser C. The charging current of the central section of the latter passes to ground in alternate half waves through the resistances and kenotrons R_1, K_1, and R_2, K_2. The currents in R_1 and R_2 are therefore pulsating but unidirectional and so may be read by a continuous-current instrument in series or in shunt, as shown in Fig. 1, G_1 being a sensitive d'Arsonval galvanometer critically damped. A second galvanometer G_2 and a telephone T are used to detect the first appearance of corona on the central rod of the corona voltmeter as described below. A number of auxiliary circuits have been omitted from Fig. 1 and will be referred to in connection with the various measurements.

We will now describe in turn the methods of measuring the charging current, the frequency, and the capacity of the condenser, together with the precautions taken, the limits of accuracy, and all leading to the determination of the value of voltage present on the first appearance of corona in the corona voltmeter B.

(*a*) *Charging Current.* Balance in kenotron circuit. In formula (4) i is the average value of the charging current. In Fig. 1 all positive half waves will pass through one kenotron and all negative half waves through the other. The d'Arsonval galvanometer in shunt to the resistance R_1 will therefore receive a

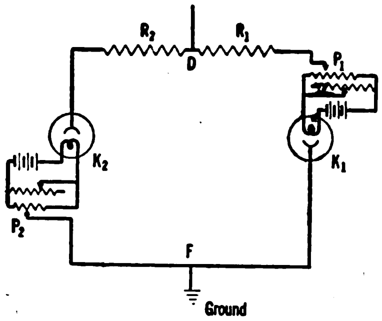

FIG. 2—KENOTRON CONTROL

tion the galvanometer will read one-half the average value of the charging current. In view of the foregoing it is of first importance that when no charging current is passing there be no continuous current flowing in the closed circuit $K_1 D K_2 F$. This condition was realized by the adjustment of the point of connection to the filament exciting circuits of the kenotrons as indicated at $P_1 P_2$ in Fig. 2. This in pulsating unidirectional current and show a deflection proportional to its average value. Obviously the combination may be calibrated directly in terms of continuous current in R_1 and in terms of such a calibra-effect interposes a small adjustable e. m. f. counter to the normal direction of conductivity, at each kenotron. If this is not done the normal leak of electrons from the filament, particularly at its negative end, results in a small current in the circuit $K_1 D K_2 F$. In making these adjustments the galvanometer G_1 was connected first in series in the circuit $K_1 D K_2 F$ and then between the points D and F, repeating with adjustments at P_1 and P_2 until both readings are simultaneously zero. After balancing the kenotron circuit, as above, it was connected into the condenser ground circuit and with alternating voltage on was further balanced for equal resistance in the two branches by adjustment for zero current in the galvanometer connected across $D F$; on removal of the alternating voltage the circuit $K_1 D K_2 F$ is still balanced. Without these adjustments a small error is possible, the galvanometer G_1 in the connection of Fig. 1 showing at times a deflection of 0.5 mm.; after

the adjustments mentioned no deflection can be detected.

(*b*) *Influence of Wave Form.* The use of the kenotrons for rectifying the charging current introduces an error if the wave form of voltage is not smooth, *i. e.*, if it has more than one maximum in each half wave. In this case there is a reversal of condenser current following every such maximum or elevation in the wave and since the kenotron passes current in only one direction, this reverse current passes through the opposite kenotron and so does not contribute to the galvanometer reading. Similarly in the next half cycle the reverse current is recorded in the galvanometer as positive. Thus due to both half waves the result is a galvanometer reading higher than that corresponding to the average charging current.

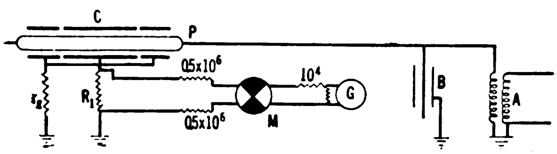

FIG. 3—MEASUREMENT OF CONDENSER CHARGING CURRENT WITH SYNCHRONOUS COMMUTATOR

The generator used in the experiments has a surface wound armature and shows a smooth wave on an oscillogram. The inserts of Figs. 4 and 5 show the voltage waves as taken from a low-tension tertiary coil on the transformer T, Fig. 1, for series and parallel connections respectively of the two primary coils. In order, however, to answer this question definitely, the wave form of the voltage at the high-tension terminals was taken by the method indicated in Fig. 3, in which

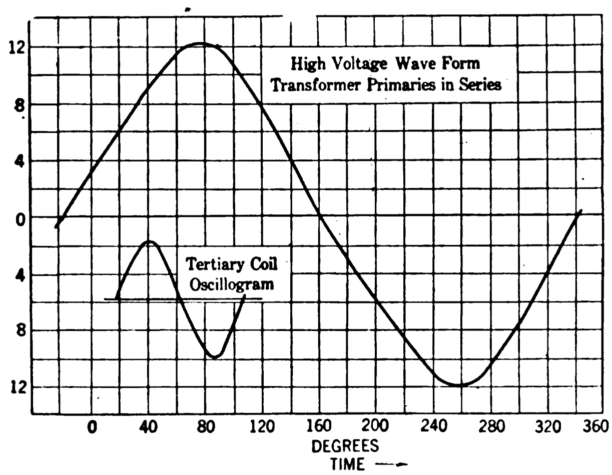

FIG. 4—HIGH-VOLTAGE WAVE FORM

M is the synchronous comutator connected as full rectifier or as half-wave suppressor. In this method first pointed out by Bedell,[9] for any position of the brushes the galvanometer reading is proportional to the average value of the charging current for any particular half-wave interval between the brushes, and this in turn is proportional to the instantaneous value of the voltage on the condenser. Figs. 4 and 5 show the wave forms so taken for series and for parallel connections respectively of the transformer primary coils, which together with Table I, giving a section from the complete sheet of readings, indicate the conditions of accuracy. The mean values of right and left readings of the galvanometer are taken in all cases in order to eliminate a slight right and left dissymmetry probably due to electrostatic disturbance, generally noticeable in the very sensitive galvanometer, in spite of most careful screening. For obvious

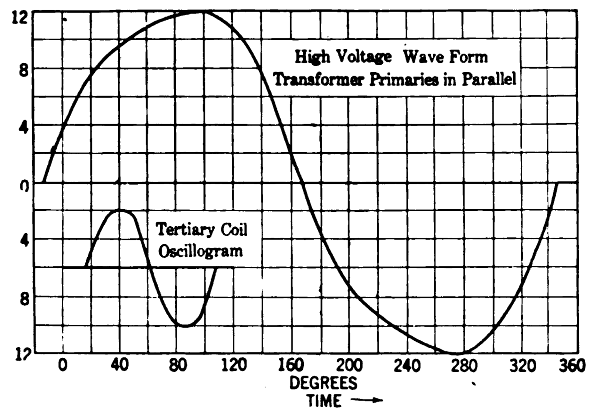

FIG. 5—HIGH-VOLTAGE WAVE FORM

reasons this disturbance is more pronounced in the half-wave measurements in which the galvanometer is used as a half-wave suppressor.

The curves of Figs. 4 and 5 were each taken at the critical or corona-forming voltage using the same corona rod and equal values of air density. Although there are noticeable differences in wave form and in

TABLE I.

WAVE FORM OF HIGH VOLTAGE

Brushes degrees	Galvanometer deflection cm.					
	Full wave			Half wave		
	Left	Right	Mean	Left	Right	2 X Mean
22.5	7.80	7.76	7.78	3.72	4.10	7.82
30	8.41	8.47	8.44	4.09	4.39	8.48
37.5	9.14	9.10	9.12	4.42	4.70	9.12
90	11.91	11.87	11.89	5.87	6.03	11.90
120	10.68	10.60	10.64	5.32	5.30	10.62

the values of effective voltage at the terminals of the tertiary coil (38 volts and 34.5 volts respectively) it is seen that the maxima of the two waves have very closely the same values. Further evidence that no error was present due to irregularities of wave form is found below in the comparison of corona readings taken with kenotrons and with commutator.

Continued on page 511

High-Tension Insulator Porcelain

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Porcelain used in the manufacture of high-tension insulators must meet certain requirements as to mechanical strength, ability to resist, sudden changes of temperature, porosity, homogeneity and temperature, coefficient of resistivity. A further suggestion as to the influences of the Piezo electric effect and the deterioration of seemingly perfect porcelain is presented with a brief discussion of the degree of progress made in the art to date.

Introduction

While in the case of transmission line insulators it is true that the design of the insulators insofar as the utilization of the material is concerned is a matter of most efficient design of air insulators, that is, the boundary surface between the air and the supporting dielectric, the material of the insulator itself becomes of greater importance as the voltage of the line increases.

The shape design of the insulator will not be discussed here as that subject is reserved for a later communication. It is hoped that the following discussion of the factors affecting the material employed in the manufacture of high-tension insulators as a dielectric, may lead engineers to a more serious consideration of this vitally important question. The discussion is confined to porcelain as for many reasons this material has come to be accepted as the best for high-tension insulators.

Factors to be Considered in the Selection of a Porcelain Body as a Material for High-Tension Insulators

Mechanical Strength. It is perfectly obvious that mechanical strength is one of the prime factors to be considered in an insulator material. One of the first duties of an insulator is to support the conductor, and it must do so under any conditions not severe enough to destroy some other element of the transmission line construction.

Insulators made today either in pin or suspension types, use porcelain either in compression or tension or both, and so it is of great importance to know the strength of porcelain under these conditions.

Porcelain being a brittle or rigid substance like cast iron, has no yield point as commonly known, and its first yield is complete rupture. There seems to be no indication that the stressing of porcelain to a point close to its ultimate strength injures it either mechanically or electrically. Indeed, the accumulated evidence of a large number of tests covering combined electrical and mechanical tests, fatigue tests and high-frequency tests indicate that such stressing has no effect whatever upon these properties. It is probably quite safe to say that properly vitrified porcelain must be stressed beyond its ultimate strength to rupture it even under repeated strains. Tension and compression tests both confirm this statement.

It is, therefore, immaterial whether the porcelain be used for compression or tension, provided that maximum momentary stress does not reach the ultimate strength of porcelain. For engineering reasons an ample safety factor must always be provided for. Ordinary porcelain, made up of the usual three ingredients,—clay, flint and feldspar— has been found by several investigators to have strengths reaching as a maximum 40,000 lb. per sq. in. for compression and 1500 lb. per sq. in. for tension. Naturally different proportions of these ingredients produce a porcelain, or to use a ceramic term, "Body," (which covers all bodies made up of the above or similar ingredients and vitrified) of somewhat different mechanical characteristics, but these figures cover rather the upper limit of strength for a body having the required characteristic as to dielectric qualities and ability to withstand sudden temperature changes.

The wide difference between these values has led many engineers to distrust porcelain used under tension, but provided the stresses are kept within the proper limits, from an engineering safety factor point of view, there is no more valid ground for this attitude than there is to condemn cast iron whenever used in tension.

Under the stimulus of the demand by transmission engineers for better insulation a great deal of work has been done on porcelain mixtures or bodies, and certain types are now available, whose strength runs up to 65,000 lb. per sq. in. in compression and 12,500 lb. per sq. in. in tension. This, indeed, is not the ultimate limit, as indications point to the commercial production of bodies with even greater strength which will at the same time retain the other necessary requirements.

In making tension and compression tests on porcelain it is very necessary that the application of the stress be made in such a manner as to place the porcelain either in pure compression or tension as desired. The compression tests are made on small blocks and the pressure applied through lead or blotting paper disks. The tension tests are made on test pieces consisting of a short, straight section of accurately determined area between two conical end pieces. These conical end pieces are gripped in a specially designed multiple part clutch faced with soft lead or blotting paper sheets; and remarkably consistent results are obtained in this manner.

Ability to Resist Sudden Changes in Temperature. A great many insulator failures are traceable directly

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to the inability of certain porcelain bodies to resist sudden changes in temperature. The first rays of sunlight on a frosty morning have often been the signal for insulator failures directly attributable to this weakness.

Also a body sensitive to this change is more difficult to manufacture reliably as it will develop internal strains which, added to the applied service strains, will produce rupture of the porcelain at very low applied loads. The existence of these strains has been shown by polarized light under microscopic examination.

Any mixture or body that in the shape and size employed will not, when completely equipped with hardware, withstand an indefinite number of alternate immersions in boiling and freezing water, should never be employed in the manufacture of high-tension insulators. This test should be insisted upon by purchasing engineers. Such bodies are made today, and some are made that will stand even greater ranges. At least two are known which can be heated red hot and thrown into a bucket of water without cracking.

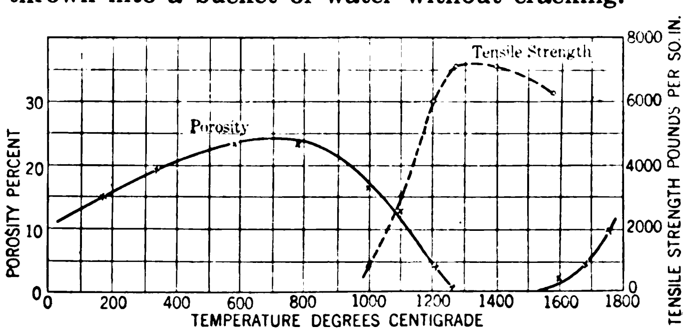

FIG. 1—POROSITY AND TENSILE STRENGTH CHARACTERISTICS—SPECIAL PORCELAIN BODY

Porosity. Porous porcelain is responsible to a large degree for the unsatisfactory condition of the insulator situation of today. One of the greatest insulator manufacturers has recently stated in a published article that non-porous porcelain cannot be produced.

This statement is challenged as the writer's investigations, both in this country and in the laboratories of France, indicate that it can be produced and under manufacturing conditions. Porcelain can be, and is, produced today that is in an engineering sense, absolutely non-porous. This statement is made after a great deal of careful research and on the strength of many porosity tests both by the impregnation method and the method used in ceramic analysis with a psychometer and a sample crushed to a 100-mesh fineness. The impregnation test has been carried in our laboratories to very high pressures, and is so penetrating that, under microscopic examination of the penetration of the colorant material, it has been observed in the cleavage cracks of microscopic quartz crystals.

Furthermore, a body having the slightest porosity, as indicated by the psychometer test, shows a decided penetration under the impregnation test.

Porosity is of two kinds, discussed in ceramic language as open pore and closed pore types. In the open pore type the pores or voids are connected by capillary passages, while in the second, or closed pore type, the voids or pores are isolated. Though the percentage of porosity may be the same in the two cases, it is obvious that the general character of porosity and its effect on insulators is different in the two cases. In general, the first form is a product of under-firing and the second of over-firing, though many instances have been found wherein over-firing produces the first type of porosity. There are probably many ceramists even today, who will dispute the statement that over-firing will produce porosity, but it can be very readily demonstrated by proper tests. In this connection the curve of Fig. 1 shows the behavior of one mixture or body and indicates very well the effect of the temperature of firing on the porosity of the body. The porosity developed on over-firing on this body was of the closed pore type and on under-firing of the open pore type. In securing the data for making this curve the samples were fired to given temperatures and cooled, and the porosity and tensile strength values were taken at room temperature. In other words the points on the curve represent maximum temperature of firing of each sample and not the temperature of the test. The porosity determinations were made by the psychometer method, the impregnation method being in any case merely qualitative.

In practise the effect of open pore type of porosity is too well-known to discuss here. The development of megger and buzz stick tests are ample evidence of the degree to which this factor has entered into the troubles encountered in the insulator field. Tests to determine porosity in units at the factory are needed, and the man who develops a method whereby we can detect porous insulators at the factory without destroying them, will be a true benefactor of the transmission engineers and porcelain manufacturers.

In the production of insulators a method has been developed that is very valuable in production control testing. A solution of fuchsine dye in wood alcohol is used and unglazed pieces placed in it under pressure. The slightest degree of porosity of the open pore type is indicated by a deep penetration of the dye into the body of the test piece. Indeed, as mentioned before, it is so penetrating that the microscope has shown it forced into the cleavage cracks of minute quartz crystals. If test pieces of the same shape and volume as the insulators being fired are properly distributed in the kiln the fuchsine test on these pieces will furnish a very reliable indication of the condition of neighboring pieces as to porosity.

Some very interesting developments have recently been brought out by the use of very high pressures on the solubility of porcelain in water under certain conditions, and it is probable that considerable light will soon be thrown upon certain types of insulator depreciation as a result of these developments.

It has been found possible to produce insulators of non-porous porcelain within the ordinary limits of quantity manufacture and by means of this method of control to prevent the porous insulators, a few of which are unavoidable in commercial manufacture, from going to the customers. Closed pore porosity is commonly indicated by a swelling of the insulators, and can be watched closely by gauges applied to the finished product.

Temperature Resistivity Coefficient. The temperature resistivity coefficient of porcelain is large and negative. The curves of Fig. 2 give an idea of this characteristic and of the improvement that has been made in it. The curve marked "Conventional Porcelain" in Fig. 2 is the standard mixture of clay, flint and feldspar, and the curve marked "New Body" is one of the recent developments, the formula for which naturally cannot be disclosed. In this curve the points on the curve represent measured resistance attained at the temperatures noted by the abscissas of the curve. For instance, a certain sample of conventional porcelain will have a resistance of two megohms at slightly over 700 degrees fahr. (371 deg. cent.) whereas the "New Body" in an exactly similar piece has a resistance of two megohms at 1160 degrees fahr. (627 deg. cent). These curves will give some idea of the progress that has been made in this respect. The importance of this feature has been discussed by various writers, and it must be stated here that this characteristic may be improved but will always be negative even in pure quartz. It has an important bearing on the mechanism of insulator failures under transient voltages. This has been discussed by the writer in previous papers before the institute.[1]

Piezo Electric Effect. One of the most baffling difficulties in the insulator situation is the deterioration of seemingly perfect units after a time, and the acquiring by non-porous porcelain of a certain porosity. Some recent investigations indicate that this may be intimately connected with Piezo electric qualities of quartz crystals. Under the microscope it will be seen that porcelain as ordinarily made, consists of rather large particles of quartz in a vitreous magma. It is well-known that if certain crystals such as quartz are subjected to a pressure on two diametrically opposite faces which are parallel with the major axes, a potential difference is set up on the faces perpendicular to those upon which the pressure is applied, which varies directly as the pressure.

The converse of this is also true and if a difference of potential is applied to two opposite faces parallel to the major axes the crystal is subjected to a squeezing action and a change in dimensions of the crystal results. These changes in dimensions if strongly resisted by the surrounding magma will set up enormous local stresses beteen the magma and the crystals.

Now what happens when this porphyritic mass is placed in an alternating electro-static field? According to the theory of probabilities a large number of these quartz crystals are so arranged that their major axes are not parallel to the field of force. This alternating field applying potentials as described will set up in these crystals a change in mechanical dimensions 120 times per second in the case of a 60-cycle system. This will result in a vibratory movement of these crystals. This vibratory action may be detrimental in two ways,—first a rupture of the crystal itself, along cleavage planes, and second a rupture between the crystals and the surrounding magma.

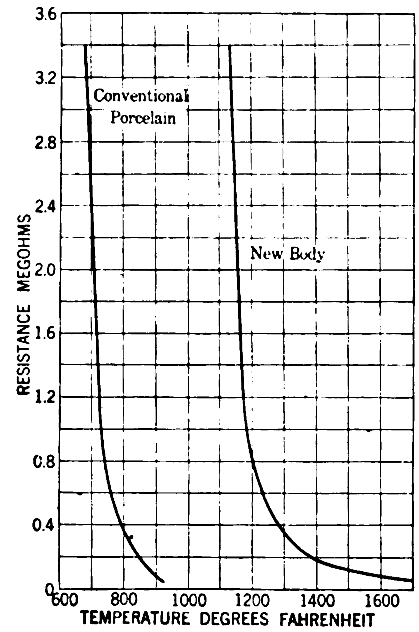

Fig. 2—Temperature Resistance Characteristics of Conventional and New Bodies

A concentrated leakage current results through the spaces between the magma and the crystals when the crystal is at its greatest deformation and the potential differences are at maximum. It will also tend towards making the porcelain porous in an entirely different manner (that is, by cracks and fracture voids) from the types before mentioned and the vibratory action of the crystals may aid in the introduction of moisture into the body. This decreases its value as a dielectric and as mentioned before the solvent action of such moisture may have an accelerating effect upon the deterioration of the porcelain.

Regardless of the degree to which this effect contributes to the deterioration of the porcelain when in service on high-tension lines the body to be sought is one wherein the quartz is dissolved as completely as possible in the feldspathic magma.

Great progress has been made in this direction and in a later communication some data, which is now

1. "Insulator Failures Under Transient Voltages," W. D. A. Peaslee, A. I. E. E. Transactions, page 1237, Vol. 35; "Insulator Situation....," W. D. A. Peaslee, A. I. E. E. Transactions, page 401, Vol. 36.

being prepared, may be given that it is hoped will be of some help in the solution of this ever present problem.

CONCLUSION

The insulator problem at present is one whose solution is to be sought in the ceramic field. Aside from more rational shape design on the part of electrical engineers, the improvement must come in the development of porcelain bodies which meet, to the greatest degree possible, the above requirements. Great progress has been made in this respect and the statement that we may very soon see the commercial production in insulator form of such bodies is now amply warranted.

Reactive Power and Magnetic Energy

BY JOSEPH SLEPIAN

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The relation between reactive power and magnetic and electrostatic energies is stated and proved and its utility is illustrated by deriving the connection between reactive power and the size of machines, between the magnetic energy of an a-c. system and the field excitations of the synchronous machines therein, and by giving the physical significance of power factor under unbalanced conditions.

IT is a matter of common knowledge that where a magnetic field is maintained by alternating currents, reactive or wattless power must be supplied. The exact quantitative relation between the reactive power and the magnetic field is not so generally understood, probably because the proportionality is between reactive power and total magnetic energy, and this last quantity is not often used by electrical engineers. In this paper a quantitative statement of the relation is given, and its utility is illustrated by several examples.

The relation which is given here is subject to certain limitations which are brought out in the appendix where the proof of the relation is given. For practical purposes the relation may be said to hold for all combinations of condensers, resistors, and inductive apparatus, stationary, oscillating, rotating, single-phase or polyphase, balanced or unbalanced, excepting commutator and homopolar machines.

To state the relation, suppose we have any combination of apparatus of the kind just described, with an arbitrary number of terminals having certain periodically varying potentials, and carrying certain periodically varying currents. These periodically varying potentials and currents may be resolved in the usual way into pure sine-wave components of different frequencies. For each frequency, the reactive power at each terminal may be calculated in the usual way. If now the reactive powers of each frequency are divided by the frequency, and the whole added together, the result equals 4 π times the mean magnetic energy minus the mean electrostatic energy.

$$\sum \frac{\text{Reactive power}}{\omega} = 2\,(T_m - T_e)$$

If there is only one frequency, the relation reduces to

$$\text{Total reactive power} = 2\,\omega\,(T_m - T_e)$$

which has been derived for static apparatus before.[1] The mean is taken with respect to time. In balanced polyphase machines the total magnetic and electrostatic energies are nearly constant at all parts of a cycle, but in unbalanced polyphase and single-phase machines the electrostatic and magnetic energies have large pulsations with frequency twice that of the supply line.

Where there is a d-c. component of voltage and current, both the reactive power and the frequency are zero, so that indeterminate forms appear in the relation as given. In this case, as is shown in the appendix, these terms should be replaced by $\Sigma\,\Phi\,I\,.\,\frac{1}{10^8}$ where I is the d-c. component of current flowing in any coil or branch, and Φ is the d-c. component of flux linking that coil or branch.

REACTIVE POWER AND THE SIZE OF MACHINES

Magnetic energy is believed to reside wherever there is a magnetic flux, the energy being distributed throughout the magnetic field. The magnetic energy density is given by $\frac{1}{8\,\pi}\,.\,\frac{B^2}{\mu}\,10^{-7}$ joules per cm.^{3}, where B is the flux density and μ is the permeability. This gives a direct relation between the reactive power taken by an induction machine without d-c. excitation, and its general dimensions. For such a machine, if currents of one frequency are supplied, we have

Total Reactive Power = 2 ω (Mean magnetic energy

On the other hand,

Mean magnetic energy

$$= \frac{10^{-7}}{8\,\pi}\left[\frac{(\text{Volume of iron}) \times (\text{Mean } B^2 \text{ in iron})}{\mu} + (\text{Volume of air gap}) \times (\text{Mean } B^2 \text{ in air gap})\right]$$

To be presented at the Annual Convention of the A. I. E. E., June 29—July 2, 1920.

[1] 1. Inherent Limitations in Transformations Possible by Static Apparatus, J. Slepian, A. I. E. E. TRANSACTIONS, 1919.

Hence,
Total Reactive Power

$$= \frac{10^{-7} f}{2} \left[\frac{(\text{Volume of iron}) \times (\text{Mean } B^2 \text{ in iron})}{\mu} + (\text{Volume of air gap}) \times (\text{Mean } B^2 \text{ in air gap}) \right]$$

This relation was discovered independently by Mr. H. G. Jungk, from calculations on a line of railway motors.[2]

A similar relation connects the reactive power supplied by a condenser, and the volume of its dielectric. Since electrostatic energy density is given by

$$\frac{10^{-7} D^2}{8 \pi \epsilon} \text{ joules/cm.}^3$$

where D is the electric flux density, and ϵ the dielectric constant, we have
Reactive Power taken by Condenser

$$= f/2 \left(\frac{\text{Volume of dielectric} \times \text{Mean } D^2}{\epsilon} \right) . 10^{-7}$$

Energy of an A-C. System and the Current Flux Linkages of its Field Circuits

An interesting connection between the total magnetic energy of an alternating-current system and the exciting direct currents may be found by applying the principle of this paper to a whole a-c. system. In making this application, we must exclude the exciters, because they are commutator machines to which the principle does not apply. Hence the field terminals of the generators, and synchronous motors are the terminals to which the principle refers, the circuits of all other current-carrying members being closed in the system itself, thus giving no external terminals. We get then

$$\frac{1}{10^8} \Sigma \Phi I \text{ for all d-c. fields in system}$$
$$= 2 \text{ (Total Mean Magnetic Energy of System Minus Total Electrostatic Energy of System)}$$

Let us take a specific example. Suppose we have a generator whose field is controlled so as to give constant voltage. This means of course, that the main flux is nearly constant. On open circuit, the only magnetic energy is that corresponding to the main flux, and the field current is such as to make $\Sigma \Phi I$ take the appropriate value,

$$\frac{1}{10^8} \Sigma \Phi I = 2 \times \text{(Energy of main flux)}$$

Suppose now a unity power factor load is drawn from the generator. The main flux must be increased somewhat to keep the voltage at the armature terminals constant, and at the same time, additional magnetic energy appears in the form of leakage flux of the armature. The corresponding field current satisfies the relation

$$\frac{1}{10^8} \Sigma \Phi I = 2 \text{ (Energy of main flux + Energy of leakage flux)}$$

If a zero per cent power factor lagging load is substituted for the unity power factor load just considered, the exciter current must be further increased due to the magnetic energy of the load.

$$\frac{1}{10^8} \Sigma \Phi I = 2 \times \text{(Energy of main flux + Energy of leakage flux + magnetic energy of load.)}$$

If a condenser load is drawn, the exciter current must be decreased corresponding to the equation

$$\frac{1}{10^8} \Sigma \Phi I = 2 \times \text{(Energy of main flux + Energy of leakage flux} - \text{electrostatic energy of load.)}$$

If the generator is self-exciting on the capacity load, I is zero, and from the last relation we get as a necessary condition for self-excitation,

Electrostatic Energy of Capacity Load
= Magnetic Energy of System.

Consider a generator A, supplying a synchronous motor B. If the voltage at the generator is kept constant, the magnetic energy in each machine is nearly constant, varying somewhat by the amount of leakage flux. If B is without excitation, we must have

$$\frac{1}{10^8} \Sigma \Phi_A I_A = 2 \text{ (Magnetic energy of } A + \text{Magnetic energy of } B)$$

When B is excited, the field current of A must receive a corresponding diminution as we must have

$$\frac{1}{10^8} \Sigma \Phi_A I_A + \frac{1}{10^8} \Sigma \Phi_B I_B = 2 \text{ (Magnetic energy of } A + \text{Magnetic energy of } B.)$$

The mutual dependence of the field currents of synchronous machines operating in parallel on a system is thus clearly shown.

Power-factor Under Unbalanced Conditions. Vectorial Kv-a. Sum Formula

Under balanced conditions power factor is defined as the cosine of the acute angle of a right triangle having for adjacent and opposite sides respectively, the total true power and total reactive power of the circuits being measured (Fig. 1). For unbalanced circuits no definition has been generally agreed upon.

It has been proposed as one definition, to construct kv-a. triangles for each phase, using line current and

2. The relation as found by Mr. Jungk is
Total Magnetising kv-a. = $B^2 S g f \times$ sat. factor $\times 10^{-11}$
where B = max. density lines /in²
$S = \pi D L$, air gap surface in square inches.
g = effective gap, one side, in inches.
f = frequency
sat. factor $= \dfrac{\text{ampere turns, Iron + gap}}{\text{ampere turns, gap}}$

voltage to neutral, then to add the hypotenuses of these triangles vectorially, and to take the cosine of the angle of this resultant as the power factor. It is clear from Fig. 2 that the triangle corresponding to this resultant has for its base the sum of the true powers supplied to the individual phases, and for its altitude the sum of the reactive powers supplied to the individual phases.

This definition has the advantage that the quantities it uses have actual physical significance. The base of the triangle gives the total real power supplied to the load being measured, and the altitude gives the excess of the mean magnetic energy of the load over the mean electrostatic energy. A pure resistance load according to this definition will always have one hundred per cent power factor irrespective of the unbalance of the load resistances or impressed voltages.

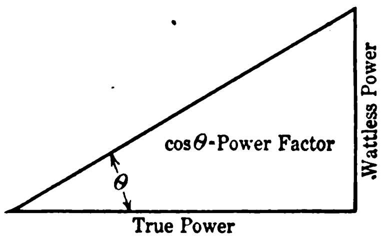

FIG. 1

Under this definition, however, all apparatus will not have this property of giving the same power factor irrespective of voltage unbalance. Rotating induction machines are particularly sensitive in this respect, and when measured according to this definition would show very low power factor when operated under unbalanced voltages. The conditions in a rotating induction machine can best be understood and analyzed by resolving the unbalanced quantities into polyphase or symmetrical components.

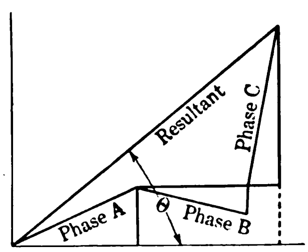

FIG. 2

For clearness let us consider a three-phase induction motor, with low-resistance secondary, running at small slip, with ungrounded neutral, so that voltages tending to produce neutral currents may be neglected. It has been shown[3] that the voltages impressed upon the motor terminals, however unbalanced, may be regarded as two component systems superimposed or simultaneously impressed; the component systems are each individually balanced three-phase voltages, but one is of normal or positive phase sequence, while the other is of opposite, or negative, or counter-rotational phase sequence. A given unbalanced three-phase voltage can be resolved into these symmetrical components in only one way. In ordinary slightly unbalanced systems, the negative or counter-rotational component of voltage is small. It has been shown for the induction motor[4] that each symmetrical component of voltage may be considered as acting as if the other component were absent. Thus to calculate the currents in the different phases of the motor under unbalanced voltage, we may calculate the currents which each symmetrical component of voltage would produce were it acting alone, and then add these two current systems together as they appear in the different phases. The problem of operation under unbalanced voltage is thus reduced to two problems under balanced voltages. The direct-rotational or positive phase sequence voltage produces direct-rotational currents; the counter-rotational voltage produces counter-rotational currents. These are the two symmetrical components of the resultant unbalanced currents. To get the unbalanced resultant currents we add together in each phase the currents corresponding to the two symmetrical components.

As with currents, so with fluxes. Each component of voltage produces flux as if the other component of voltage were absent. The resultant flux distribution under unbalanced voltage may be obtained by combining the fluxes corresponding to each component of voltage taken separately. It may be shown[5] that the mean magnetic energy of the resultant flux is equal to the sum of the magnetic energies of the fluxes corresponding to the polyphase components taken separately.

When running at a small slip, the direct-rotational flux consists mostly of the synchronous direct-rotating main flux and a small leakage flux. Because most of the magnetic energy here resides in the main flux, a relatively high direct-rotational voltage is necessary to maintain it. The counter-rotational components, however, are all at nearly 200 per cent slip relative to the rotor, and therefore, owing to the magnetic damping of the rotor, the counter rotational flux consists mostly of leakage flux between primary and secondary, and to a small extent of counter-rotating main flux. A relatively small counter-rotational voltage therefore may produce considerable counter-rotational magnetic energy.

The conditions for reducing the magnetic energy, and thus giving good power factor, under direct-rotational voltage, *e. g.* small air gap, good magnetic coupling between primary and secondary windings, etc., are just the conditions for giving excessive magnetic energy and low power factor under counter-ro-

3. Fortescue, A. I. E. E. TRANS. Vol. XXXVII p. 1027, 1918.

4. Fortescue loc. cit.

5. Slepian, A. I. E. E. TRANS. Vol. XXXVII, 1918 Discussion, p. 661.

tational voltage. An induction motor designed for a high power factor under normal balanced voltage conditions, would, if measured according to the vectorial kv-a. definition, show a low power factor under voltages which are only slightly unbalanced.

A case in point was brought to the attention of the author, where a synchronous converter was sold with the guarantee of giving 100 per cent power factor at rated load. The leads from the transformers to the slip rings were installed by the customer in an unsymmetrical way, causing a considerable unbalance in the voltages at the slip rings. The power factors taken from the three diametrical pairs of rings were all different, and the question arose as to what would represent 100 per cent power factor. It was finally agreed that the guarantees would be met if 100 per cent were maintained on one diameter, with equal power factors on the other two, leading on one, and lagging on the other. Since the kv-a. in all the leads were nearly equal, this was evidently equivalent to adopting the vectorial kv-a. definition of power factor.

It is clear from the preceding discussion that this was unfair to the manufacturer. Under the test conditions agreed upon the field excitation was raised high enough to have given leading power factor if the voltages had been balanced. With the voltages unbalanced the rotary was taking a large counter-rotational magnetic energy, and therefore correspondingly large counter-rotational reactive current. It was then called upon to give an equal amount of direct-rotational reactive current, but leading, which meant leading direct-rotational power factor and higher field excitation than the manufacturer had anticipated. Stated in another way, at unity power factor under this definition we have if i is the field current

$$\frac{1}{10^8} \Sigma \, \phi \, i = 2 \text{ (Total magnetic energy)}$$

If the voltages are balanced, all this energy is direct-rotational,

$$\frac{1}{10^8} \Sigma \, \phi \, i = 2 \text{ (Direct-rotational magnetic energy)}$$

A slight voltage unbalance will give considerable counter-rotational magnetic energy, and this calls for a considerable increase in field current since

$$\frac{1}{10^8} \Sigma \, \phi \, i = 2 \text{ (Direct-rotational magnetic energy + counter-rotational magnetic energy)}$$

Power Factor Under Unbalanced Conditions. Direct-Rotational Component Definition

If rotating machines are to be given a power factor descriptive of their operation under normal conditions, it is evident that some definition other than that of the preceding section must be used when measurements are made under unbalanced conditions. In the light of the preceding discussion, the following would appear to be a satisfactory definition of power factor, under unbalanced voltage conditions, of a balanced rotating machine. Power factor is the cosine of the angle of lag between the direct-rotational component of voltage and the direct-rotational component of current. Methods for determining from the observed unbalanced voltages and currents, the direct-rotational components and the angle between them are beyond the scope of this paper. With this definition, a balanced rotating machine will show the same power factor irrespective of the voltage unbalance.

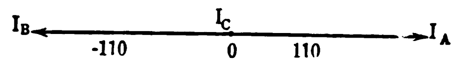

Fig. 3

What is the state of affairs, however, when this definition is applied to apparatus which is inherently unbalanced? This is best brought out by a simple example. A three-phase generator, $\frac{110}{\sqrt{3}}$ volts to neutral, is supplying a pure resistance load of one ohm, across one phase. What are the line voltages, currents, and the power factor under the last definition in this case? The power factor under the first definition, of course must be 100 per cent. The current through the resistance will be 110 amperes. The currents in the three lines will be as shown in Fig. 3, line A I_A = 110 amperes; line B, I_B = − 110 amperes; line C,

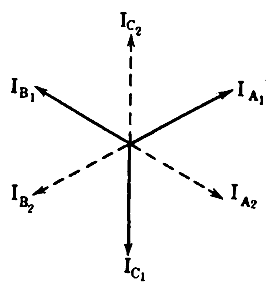

Fig. 4

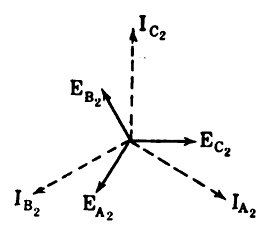

Fig. 5

I_C = 0 amperes. Resolving these currents into symmetrical components, we get for the direct-rotational component (heavy lines, Fig. 4) line A, $I_{A1} = 55 + 55\sqrt{3}\,j$ amperes; line B, $I_{B1} = -55 + 55\sqrt{3}\,j$ amperes; line C, $I_{C1} = -110\sqrt{3}\,j$ amperes. For the counter-rotational component we have (dotted lines, Fig. 3) line A, $I_{A2} = 55 - 55\sqrt{3}\,j$ amperes; line B, $I_{B2} = -55 - 55\sqrt{3}\,j$ amperes; line C, $I_{C2} = +110\sqrt{3}\,j$ amperes.

The counter-rotational currents, (I_{A2}, I_{B2}, I_{C2}) when drawn from the generator, produce counter-rotational voltages at the terminals (E_{A2}, E_{B2}, E_{C2}), which lag nearly 90 deg. behind the currents, see Fig. 5. The magnitude of the counter-rotational voltage wil

depend upon the closeness of coupling between the armature of the generator and the damper winding on its field. The magnitude of the direct-rotational voltage depends upon the field excitation. Suppose this is adjusted to give 110 volts total between lines A and B. From this condition, since further this voltage must be in phase with the current through the resistance, the direct-rotational voltage (E_{A1}, E_{B1}, E_{C1}) is readily determined (Fig. 6.). In Fig. 6, we see that the direct-rotational current lags behind the direct-rotational voltage so that the pure resistance load actually draws direct-rotational reactive power. Thus its power factor according to the direct-rotational component definition would be less than 100 per cent. From Fig. 5 we see that all the counter-rotational power is leading reactive power. This might have been foreseen, for since the total reactive power taken by the resistance load is zero, whatever is taken in direct-rotational form must be returned to the line in counter-rotational form.

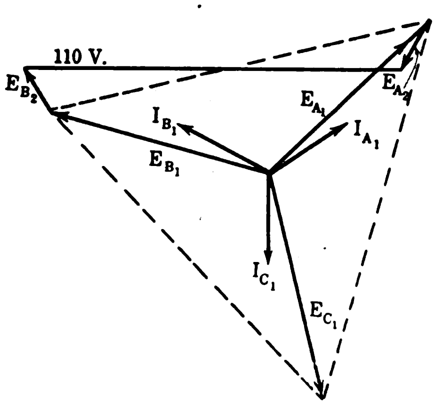

FIG. 6

The field excitation will be that corresponding to the direct-rotational voltage, current, and power factor. It is thus larger than that which would be required for an equal load which is balanced. This is because with the unbalanced load there is actually more magnetic energy in the system. The unbalanced resistance load, while containing no magnetic energy itself, causes counter-rotational magnetic energy to exist in the system. This affects the field excitation according to the equation,

$\Sigma \phi i = 2$ (Direct-rotational magnetic energy + counter-rotational magnetic energy.)

where $\Sigma \phi i$ represents the total flux-current linkages of the field of the generator. By the direct-rotational component definition, in this case, the power factor of the unbalanced resistance load is dependent upon the constants of the generator.

It is not intended that this paper shall advocate any particular definition of power factor for unbalanced conditions, but merely to point out the meaning of two definitions which have been proposed. However, there seems little doubt that for rotating balanced machines, the direct-rotational component definition is the best. For unbalanced stationary apparatus, for example polyphase furnaces, it seems likely that the vectorial kv-a. formula is preferable. For this class of apparatus, a further term, an unbalance factor, would appear desirable for giving adequate description.

Power factor has been used in this paper as characterizing a piece of apparatus. It is also widely used to describe a load from the point of view of the cost of its generation and transmission. Here the considerations are somewhat different, but here also the principle connecting wattless power with magnetic energy will prove useful in discussions.

APPENDIX

PROOF OF RELATION CONNECTING REACTIVE POWER AND MAGNETIC AND ELECTROSTATIC ENERGIES

A few well-known propositions concerning the mean value of products of periodic quantities, and some expressions for magnetic and electrostatic energy which are used in the proof will first be given.

Expansion of a Periodic Quantity into a Fourier Series. Any periodic quantity can be expanded into a series of the following form,

$$y = a_0 + a_1 \sin(\omega t + \alpha_1) + a_2 \sin(2\,\omega t + \alpha_2) + \ldots$$

Each term of the expansion is called a harmonic.

Mean Value of the Product of Two Periodic Quantities. The mean value of the product of two periodic quantities is equal to the sum of the mean values of the products of harmonics of the same frequencies in the Fourier expansions of the two periodic quantities. Thus if

$$y = a_0 + a_1 \sin(\omega t + \alpha_1) + a_2 \sin(2\,\omega t + \alpha_2) + a_3 \sin(3\,\omega t + \alpha_3) + \ldots$$

$$z = b_0 + b_1 \sin(\omega t + \beta_1) + b_2 \sin(2\,\omega t + \beta_2) + b_3 \sin(3\,\omega t + \beta_3) + \ldots$$

then

$$\begin{aligned}\text{Mean of } y\,z &= a_0\,b_0 + \text{mean of } a_1\,b_1 \sin(\omega t + \alpha_1)\sin(\omega t + \beta_1)\\ &\quad + \text{mean of } a_2\,b_2 \sin(2\,\omega t + \alpha_2)\sin(2\,\omega t + \beta_2)\\ &\quad + \text{mean of } a_3\,b_3 \sin(3\,\omega t + \alpha_3)\sin(3\,\omega t + \beta_3)\\ &\quad \text{etc.}\\ &= a_0\,b_0 + \tfrac{1}{2}\,a_1\,b_1 \cos(\alpha_1 - \beta_1)\\ &\quad + \tfrac{1}{2}\,a_2\,b_2 \cos(\alpha_2 - \beta_2)\\ &\quad + \tfrac{1}{2}\,a_3\,b_3 \cos(\alpha_3 - \beta_3)\\ &\quad \text{etc.}\end{aligned}$$

Magnetic Energy. The magnetic energy of the field produced by a system of currents is given by

$$t_m = \frac{1}{2.10^8}\,\Sigma\,\phi\,i$$

$$= \frac{1}{2.10^8}\,(\phi_1\,i_1 + \phi_2\,i_2 + \phi_3\,i_3 + \ldots)\text{ joules}$$

where each term is the product of i_K the current in a branch or circuit of the system, and ϕ_K the number of

flux linkages of that branch or circuit; the summation is taken for all the branches and circuits of the system.

Electrostatic Energy. The electrostatic energy of a condenser is given by $t_e = \frac{1}{2}\frac{q^2}{C}$ joules where q is the charge in coulombs and C the capacity of the condenser in farads.

Proof of the Relation. For any branch or circuit of the system we have

$$e = r\,i + \frac{1}{10^8}\frac{d\phi}{dt} + \frac{q}{C} \qquad (1)$$

where i is the current in the branch or circuit, ϕ the flux linking the branch or circuit, q the charge on the condenser in that branch or circuit, and e the difference of potential between the ends of the branch or circuit. If the circuit is a closed loop, $e = 0$. The quantities in equation (1) are periodic, and their Fourier expansions in general will contain constant terms. Suppose these constant terms subtracted out from equation (1) leaving

$$e_A = r\,i_A + \frac{1}{10^8}\frac{d\phi_A}{dt} + \frac{q_A}{C} \qquad (2)$$

where e_A, i_A, ϕ_A, and q_A are the purely alternating parts of e, i, ϕ, and q respectively remaining after the constant terms of the Fourier expansions of these quantities have been subtracted.

Now integrate equation (2) taking that integral which is periodic. (This merely fixes the constant of integration.)

$$\int e_A\,dt = r\int i_A d\,t_A + \frac{1}{10^8}\phi_A + \frac{1}{C}\int q_A\,dt \quad (3)$$

Multiplying through by i_A and remembering that

$$i_A = \frac{d\,q_A}{d\,t}$$

$$i_A \int e_A\,dt$$

$$= r\,i_A \int i_A d\,t + \frac{1}{10^8}\phi_A\,i_A + \frac{1}{C}\frac{d\,q_A}{d\,t}\int q_A d\,t \quad (4)$$

Suppose equations similar to (4) found for all the branches or circuits of the system, and that they are all added together, giving

$$\Sigma\, i_A \int e_A\,dt = \Sigma\, r\,i_A \int i_A\,dt + \frac{1}{10^8}\Sigma\, i_A\,\phi_A$$

$$+ \Sigma\frac{1}{C}\frac{d\,q_A}{dt}\int q_A\,dt \qquad (5)$$

We may now take the mean value of each term of (5) getting

Mean value of $\Sigma\, i_A \int e_A\,dt$

= mean value of $\Sigma\, r\,i_A \int i_A\,dt$

+ " " " $\frac{1}{10^8}\Sigma\,\phi_A\,i_A$ (6)

+ " " " $\Sigma\frac{1}{C}\frac{d\,q_A}{dt}\cdot\int q_A\,dt.$

We now proceed to evaluate each term of (6).

The first term

$$\Sigma i_A \int e_A\,dt.$$

Let

$i_A = i_1 \sin(\omega t + \alpha_1) + i_2 \sin(2\,\omega_2 t + \alpha_2) + \ldots;$

let

$e_A = e_1 \sin(\omega t + \beta_1) + e_2 \sin(2\,\omega t + \beta_2) + \ldots$

Then

$$\int e_A\,dt = -\frac{e_1}{\omega}\cos(\omega t + \beta_1)$$

$$- \frac{e_2}{2\,\omega}\cos(2\,\omega t + \beta_2)\ldots$$

Hence it follows that the mean of

$$i_A \int e_A\,dt = \Sigma\frac{\text{Reactive Power}}{\omega}$$

supplied to the branch under consideration. It is readily seen that when we sum up for all the branches we get $\Sigma\frac{\text{Reactive Power}}{\omega}$ for the terminals of the system. Hence

$$\text{Mean value of } \Sigma\, i_A \int e_A\,dt = \Sigma\frac{\text{Reactive Power}}{\omega}.$$

The next term

$$\Sigma\, r\,i_A \int i_A\,dt.$$

Let

$i_A = i_1 \sin(\omega t + \alpha_1) + i_2 \sin(2\,\omega t + \alpha_2) + \ldots$

Then

$$\int i_A\,dt = -\frac{i_1}{\omega}\cos(\omega t + \alpha_1)$$

$$- \frac{i_2}{2\,\omega}\cos(2\,\omega t + \alpha_2)\ldots$$

Evidently then the mean value of $i_A \int i_A\,dt$ is zero. Hence

$$\text{Mean value of } \Sigma\, r\,i_A \int i_A\,dt = 0.$$

The next term

$$\frac{1}{10^8}\Sigma\, i_A\,\phi_A.$$

The instantaneous magnetic energy t_m is given by

$$t_m = \frac{1}{2.10^8}\Sigma\,\phi\,i = \frac{1}{2.10^8}\Sigma\,(\phi_D + \phi_A)(i_D + i_A)$$

$$= \frac{1}{2.10^8}[\Sigma\, i_D\,\phi_D + \Sigma\,\phi_A\,i_A + \Sigma\,\phi_A\,i_D + \Sigma\,\phi_D\,i_A]$$

where ϕ_D and i_D are the constant terms of the Fourier expansions of ϕ and i. Clearly the mean values of $\Sigma\,\phi_A\,i_D$ and $\Sigma\,\phi_D\,i_A$ are zero, and hence the mean magnetic energy

T_m = mean value of t_m

$$= \frac{1}{2.10^8}[\Sigma\,\phi_D\,i_D + \text{mean value of } \Sigma\,\phi_A\,i_A]$$

Hence

$$\text{Mean value of } \frac{1}{10^8} \Sigma \phi_A i_A = 2 T_m - \frac{1}{10^8} \Sigma i_D \phi_D$$

The next term

$$\Sigma \frac{1}{C} \frac{d q_A}{dt} \int q_A dt.$$

Let

$$q = q_1 \sin (\omega t + \gamma_1) + q_2 \sin (2 \omega t + \gamma_2) + \ldots$$

Then

$$\frac{d q_A}{dt} = q_1 \omega \cos (\omega t + \gamma_1) + q_2 2 \omega \cos (2 \omega t + \gamma_2) + \ldots;$$

$$\int q_A dt = - q_1/\omega \cos (\omega t + \gamma_1) - \frac{q_2}{2 \omega} \cos (2 \omega t + \gamma_2)$$

Hence mean value of

$$\frac{d q_A}{dt} \int q_A dt = - \frac{q_1^2}{2} - \frac{q_2^2}{2} - \frac{q_3^2}{2} \ldots.$$

On the other hand mean value of

$$q_A^2 = + \frac{q_1^2}{2} + \frac{q_2^2}{2} + \frac{q_3^2}{2} + \ldots.$$

Hence mean value of

$$q_A^2 = - \text{ mean value of } \frac{d q_A}{dt} \int q_A dt.$$

The instantaneous electrostatic energy t_e is given by

$$t_e = \frac{1}{2} \Sigma \frac{q^2}{C} = \frac{1}{2} \Sigma \frac{(q_D + q_A)^2}{C}$$

$$= \frac{1}{2} \left[\Sigma \frac{q_D^2}{C} + \Sigma \frac{q_A^2}{C} + 2 \Sigma \frac{q_D q_A}{C} \right]$$

where q_D is the constant term in the Fourier expansion of q. Since mean value of

$$\Sigma \frac{q_D q_A}{C} = 0,$$

mean value of $t_e = T_e =$ mean value of

$$\frac{1}{2} \left[\Sigma \frac{q_D^2}{C} + \Sigma \frac{q_A^2}{C} \right]$$

Hence

$$\text{Mean value of } \Sigma \frac{1}{C} \frac{d q_A}{dt} \int q_A dt = 2 T_e - \Sigma \frac{q_D^2}{C}$$

Substituting into equation (**6**) we have finally

$$\Sigma \frac{\text{Reactive Power}}{\omega} + \frac{1}{10^8} \Sigma \phi_D i_D - \Sigma \frac{q_D^2}{C} = 2 (T_m - T_e)$$

The detailed steps in passing from $\Sigma \frac{\text{Reactive Power}}{\omega}$ taken for each branch to $\Sigma \frac{\text{Reactive Power}}{\omega}$ taken only for the terminals are fairly obvious and so were omitted in the above proof. There is one point however, which should be brought out in this connection, as it shows a limitation ruling out the homopolar machine from the relation. It will be readily seen that where slip rings are involved, all parts must be at the same potential, and the flux linkages between any point fixed on a ring and one of the brushes must be negligible. This last rules out the homopolar machine.

THE MILITARY ENGINEER

THE MILITARY ENGINEER, formerly PROFESSIONAL MEMOIRS, the Journal of the Society of American Military Engineers, has had its first issue. As successor of PROFESSIONAL MEMOIRS, which was published by the Corps of Engineers, U. S. Army, the new Journal aims to enter a much larger field and to operate on a larger scale than its predecessor. Its purpose as stated is to form a bond of union between all members of the engineering profession who are interested in the national defense to the end that the profession may render the maximum of service to the country in case of need. Toward this end an improved and very attractive bimonthly publication is issued, containing articles on both civil and military engineering. Some extracts from the editorial in the first number are interesting:

With this issue PROFESSIONAL MEMOIRS in a new form and under a new name enters a new era, on the occasion of its twelfth birthday. It must be an era of greater usefulness than that which has passed. We have a more important mission to perform, a larger clientele to whom we must appeal.

The scope of our efforts will be greatly increased. In this issue several new departments make their appearance and certain old ones have been abandoned. The news section, which now appears for the first time, is far from being complete or perfect. Still, we feel encouraged by a good beginning.

Our change of name is in accordance with our change of policy. A "memoir" is a solemn chronicle of a task well done. But a magazine such as ours, to fulfill the mission we have set before us, should not be a mere archive of technical data and methods. It must be a living thing, pulsating with human emotion and interest.

To be instructive a magazine should be entertaining. The journal of a scientific institute, the "proceedings" of a technical society, do not serve the same purpose as a current periodical. They are in effect archives of technical knowledge, and our journal is not such. Our "body politic" consists chiefly of live human interests and passions, men who are doing things, and not "book-worms," or animated encyclopedias of impractical ideas. We aim to dispense and distribute enthusiasm as well as knowledge. Enthusiasm and knowledge combined win many battles where either alone would fail.

The aim of this journal is to promote the practical efficiency the solidarity and the enthusiasm of the engineering profession, in the service of the country.

The dues for membership in the Society or for subscription to the journal are $4.50 per annum. The journal is published at Washington Barracks, D. C.

Regional Power Development and the Low Temperature Distillation of Coal

By C. M. GARLAND
Consulting Engineer, Chicago

FROM time to time, more or less practical and comprehensive schemes are suggested for the development of regional power plants for the distribution of cheap electrical power throughout industrial districts. It is an attractive subject and one that has been given considerable thought by power engineers and economists in general. The latest of these suggestions is that presented by Mr. W. S. Murray in an address before the Connecticut Chamber of Commerce, proposing a regional power development scheme to include the North Atlantic States, a reprint of which appeared in the January issue of this JOURNAL. Mr. Murray's address is in a measure the raison d'etre of the present article.

In the generation of power, the avoidable waste of fuel alone in the United States easily reaches the value of $1,500,000.00 a day, to which may be added the loss through the lack of continuity of service, decrease in production, and the loss through the purchase and maintenance of spare equipment.

The above are the avoidable losses under present methods of power generation in public utility and industrial plants as they stand today. Combine the savings which can be effected in these plants without even attempting larger scale methods of generation and distribution with the saving that can be effected through these methods and the total savings will amount to more than $3,000,000.00 a day. Mr. Murray's figures for the saving which may possibly be effected in the Atlantic Coast States are by no means exaggerated. The inefficiency in the industrial and also in most of the public utility plants is due to the poor design of the plant, to poor load factors and to poor operation. There is not one small or medium size plant in a hundred that is designed so that it can be operated efficiently or if it is so designed, is actually so operated.

All of the above conditions leading to poor economy in the use of fuel, to the waste of natural resources, to the losses enumerated above and to railroad and terminal congestion are traceable to small scale power and heat production and Mr. Murray's proposal would certainly ameliorate some of these conditions.

The writer is convinced, however, that no regional power development scheme north of the Mason and Dixon line which contemplates the generation of power from coal is complete unless it provides heat for industrial plants in winter, and furthermore, that no regional power development scheme contemplating the generation of power from bituminous or semi-bituminous coal is more than half-way complete if it does not contemplate the recovery of the by-products from the coal.

In the central and northern portions of the United States every industrial plant for from seven to eight months out of the year requires fuel for heating. In 75 per cent of these plants, the fuel required for heating is more than sufficient to generate the power required for manufacturing operations. For practical purposes, it may therefore be considered that the power is obtained during these months without fuel expenditure. This explains why only 30 per cent of the industrial plants buy their power. Of this 30 per cent 20 per cent would doubtless be better off if they had efficiently operated plants and generated their own power. The writer is a strong advocate of central station development but believes that it is well to recognize the limitations imposed by existant conditions.

The great barrier to Mr. Murray's project is therefore the fact that the average plant can take advantage of the increased economy of the central station only for four to five months out of the year. During the winter season the same amount of coal would have to be hauled to furnish heat insofar as the industrial plants are concerned. The amount of coal hauled would therefore be reduced only by the amount of coal saved by the electrification of the railroads which in this section would not amount to more than 20 per cent of the total. The writer therefore cannot see any great relief to railroad congestion unless some other method of heating, other than direct coal firing, is resorted to. It is also this coal for heating that leads to the over-crowding of railroad terminals during the winter months. Again, it is questionable if the poorer economy certain to result from the intermittent operation of boilers for the heating load in winter, assuming that the power load was taken by the central station, would not offset the saving effected through the electrification of the railroads. It is therefore quite certain that any regional power development that does not include also the distribution of heat will be extremely limited in its success, for with the present methods of electrical power generation, it would never be possible to distribute electrical current for the heating of large areas at low temperatures.

American inventive genius and American enterprise when working on projects in popular demand and when playing to the gallery, so to speak, transcends itself. When working on more obscure matters and on less popular projects it may be accused of groveling in the dust. An excellent illustration of this is the

comparison between the development of the automobile and the steam locomotive. The former having been developed in less than twenty-five years, taking its power from a source recognized as unreliable, operating on all kinds of roads and operated by unskilled mechanics is today just as reliable, requires less attention, has fewer repairs than the latter after over one hundred years of development, when operating on roads as smooth as engineering methods can produce, and when operated by skilled mechnanics with years of experience.

The same is true of the power station. The development of the electrical end, that end which is the most spectacular and appealing to the imagination of the public has been rapid. The steam and the fuel burning ends of the power plant have lagged behind. There has been no real development in the generation of steam or the burning of fuel in the past forty years. We are still burning most of our fuel on grates that were considered modern in the stone age and are absorbing heat in boilers representing zero in engineering achievement. So it is with the recovery of the by-products from coal. The amount of the by-products, the chemical composition and the methods of recovery have been known for years. Yet, the amount of by-products recovered from fuel burnt for the production of power is insignificant.

In the United States where at least 500,000,000 tons of bituminous coal are burnt annually, there are 10,000,000,000 gallons of tar and the equivalent of 30,000,000,000 pounds of ammonium sulphate, having a combined value of $2,500,000,000.00 burnt up with the coal. It is not practicable to save all of these by-products but a recovery of 25 per cent could reasonably be expected when it is considered that 80 per cent of the coal mined is used by industrial plants, public utility plants and the railroads.

The remarkable part of all of this is that the means are at hand today and have been at hand for a number of years, for carrying out the regional power development, the regional distribution of heat, the placing of every industrial load on the central station, the relieving of railroad congestion, particularly terminal congestion, through the reduction of the hauling of fuel, the reduction of the smoke nuisance in cities, and in addition to these, the recovery of the by-products from at least 25 per cent of the coal mined.

I refer to the combination of the well-known Mond by-product system of gas generation with the low temperature distillation of coal.

In the Mond process, coal is gasified in a special producer whereby the coal is converted into gas, tar and ammonia. The ammonia is recovered in the form of ammonium sulphate which amounts to from 50 to 100 pounds per ton of coal gasified and has a value of about four cents per pound under present prices. The value of this by-product therefore varies from $2.00 to $4.00 per ton of coal gasified, depending upon the amount recovered.

The tar recovered from the straight Mond process represents about 6 per cent of the weight of the coal and this tar consists principally of pitch which has little or no value.

The gas from the Mond process has a calorific value in the neighborhood of 140 B. t. u. per cubic foot and from 65 to 70 cubic feet of gas are obtained per pound of coal. This gas can be burnt under boilers with greater efficiency than the coal and without smoke It is also suitable for use in the firing of house heating boilers and for small or large industrial furnaces.

This gas can be piped economically within a radius of fifteen miles of the central station. This distance limits the size of the central station and to a certain degree, does not accomplish everything that could be desired from regional power and heat distribution. It does, however, relieve railroad terminal congestion and it will in a large measure, relieve main line congestion, due to the greater economy in the use of fuel and to the elimination of fuel hauled for the use of railroads.

The Mond process has been in use a great many years in Europe. At South Staffordshire, England, a plant has been in operation for a number of years which distributes gas and power to an industrial district of approximately 123 square miles. The Mond process is therefore a process that has been tried out and that is today operating on a commercial basis recovering the by-product of ammonium sulphate only.

By the low temperature distillation of coal is meant distillation of coal at a temperature around 1,000 deg. fahr. When distilling coals at this temperature, a very small amount of gas is generated of high calorific value and a large amount of tar with a small amount of ammonia.

This is a process which has been experimented with for years and which has been demonstrated on a practical scale by different investigators in this country and abroad. It has been definitely determined beyond question of a doubt that from 20 to 30 gallons of tar can be obtained from a ton of bituminous coal, something like 12 pounds of ammonium sulphate and from 1 to 2 cubic feet of gas and about 75 per cent of coke.

The tar from this process contains considerable quantities of motor fuel and creosotes. It has been estimated that it would be possible by the splitting up of this tar to obtain from 15 to 20 gallons of motor fuel per ton of coal. Investigations indicate that in a crude state this tar is worth in the neighborhood of 10 cents a gallon.

The coke from this process would probably contain in the neighborhood of from 12 per cent to 15 per cent of volatile matter which would contain most of the nitrogen originally in the coal. By gasifying this coke in the by-product gas producer, from 50 to 85 pounds of ammonium sulphate will be obtained per

ton of coke gasified and from 65 to 70 cubic feet of gas having a calorific value in the neighborhood of 140 B. t. u.

The low temperature process will yield by-products having a value of from $2.00 to $3.00 per ton of coal gasified. By gasifying the coke in the by-product gas producer the ammonia recovered will have a value of from $2.00 to $4.00 per ton of coal gasified, depending upon the amount recovered. In other words, by combining these two processes, by-products having a value of from $4.00 to $7.00 per ton of coal gasified may be obtained.

The low temperature distillation of coal can be carried out in cylindrical retorts and discharged into the producers. A combination of the two processes will result in a mixed gas having a calorific value of about 150 B. t. u. per cubic foot. There are other advantages in the combination of the processes such as the simplification of the scrubbing of the producer gas due to the fact that 95 per cent of the tar comes off in the low temperature distillation.

The market for the by-products obtained from these two processes is an ever increasing market which insures either a constant price or a constantly increasing price. A large portion of the tar by-product can be used for motor fuel. The market for ammonium sulphate as a fertilizer is ever increasing. The price of ammonium sulphate up to the time of the war has remained constant for years at about three cents per pound. At the present time, the price of this product is around four cents per pound.

In this combination of the low temperature process with the Mond gas producer lies the greatest development in the power field today and it is a development requiring practically no experimentation. All the parts constituting the plant have been worked out and all that is required is the assembling.

I would not ask Congress, as Mr. Murray has suggested, to appropriate $200,000.00 to find out if there was a $300,000,000.00 waste in the Atlantic Coast States for the same reason that I would not ask Congress to appropriate $200,000.00 to ascertain if the statue of Liberty is still standing in the New York Harbor. Every engineer experienced in power plant economy knows that this waste exists and has a comprehensive idea of the magnitude of this waste. I would, however, ask Congress for an appropriation of $5,000,000.00 for the construction of a workable sized plant along the lines of the combined Mond and low temperature distillation processes. This $5,000,000.00 properly used would bring greater returns to the American people than any money Congress ever spent.

THE AMERICAN-SCANDINAVIAN FOUNDATION

The American-Scandinavian Foundation, acting upon nominations made by colleges of this country, has awarded to American students 20 traveling fellowships for study in Denmark, Norway and Sweden during the academic year 1920-1921. More than 150 application papers were considered by the committee of college professors and technological experts who made the selection of 19 of the 20 Fellows. The twentieth will be appointed later with the assistance of C. F. Marvin, Chief of the U. S. Weather Bureau, as this Fellow will be sent to study oceanography and weather forecasting at the Bergen Geo-Physical Institute, Norway. The candidates represented most of the larger American colleges, and among the Fellows and alternates appointed are students from either coast, from Harvard and Columbia, and also from the Universities of California and Oregon, and from the Universities of Illinois, Nebraska and Texas. Ten of the Fellows are appointed for study in Sweden, and five each for study in Denmark and Norway. Those who go to Sweden this year will study forestry, chemistry, physics, hydro-electrical engineering, social economy or Indic philology; in Norway they will study physics, hydro-electrical engineering, oceanography, literature, or social sciences; in Denmark, bacteriology, physiology, industrial organization, literature or music. Among those to whom Fellowships were awarded are three women, Mrs. Elizabeth P. Hunt of Bryn Mawr, Miss Helen A. Purdy of Columbia, and Miss Hanna A. Larsen, translator of Jacobsen's Marie Grubbe and Niels Lyhne. The Fellows will sail from New York in late spring or early summer, and will spend the summer in traveling about in the countries to which they are appointed, familiarizing themselves with the language and will begin study at Scandinavian institutions in the fall. These Fellowships are awarded annually and are part of an international exchange which provided also for 20 Swedish, Danish and Norwegian students at American colleges. The funds for the fellowships were pledged by Americans and Scandinavians desirous of promoting friendly relations and intellectual interchange between the countries of northern Europe and the United States.

TRADE MARK CONVENTION RATIFIED

The Buenos Aires Trade Mark Convention has been ratified by the Senate and House conferees. Changes in the conference were of a minor nature. A provision was added stating that trade marks of sufficient similarity to previous trademarks as to cause confusion and mistakes in the mind of the public or to deceive purchasers are not to be registered. A new section was added by the conferees, which will protect the rights of the American trade in foreign countries. It applies to other countries as well as to South America.

Theory of Speed and Power Factor Control of Large Induction Motors by Neutralized Polyphase Alternating Current Commutator Machines

BY JOHN I. HULL

Designing Engineer, General Electric Co., Schenectady, N. Y.

Theory of induction motor control, discussing single-range (below synchronism only) speed and power factor control by means of a constant-speed series commutator motor, by means of a constant-speed shunt commutator motor, by means of a constant-speed compound excited commutator motor; double-range (all speeds above or below synchronism) speed and power factor control by means of a constant-speed shunt commutator motor; and double-range (either above or below synchronism) operation remote from synchronism. The discussion is illustrated in detail, special attention being paid to the circle diagram.

A STATIONARY polyphase wound-rotor induction motor is merely a static transformer arranged so that the primary coils are all on one part of the magnetic circuit, and the secondary coils on another part of the magnetic circuit, the two parts thus being arranged so as to permit relative motion. The reluctance of the magnetic circuit is kept as low as possible by imbedding both primary and secondary winding in slots, thereby permitting the "teeth" between the slots of the primary iron to come as close to the "teeth" of the secondary iron as safe mechanical clearance permits. The necessity of some clearance or "air gap" makes the reluctance, hence, the magnetizing current and kv-a. larger than for the static transformer of similar capacity, voltage and frequency, while the separation of the primary winding from the secondary winding and the imbedding of both in slots make the leakage reactances larger than for the corresponding static transformer. It is thus evident that the induction motor may logically be considered from the point of view of a transformer so arranged as to permit the forces set up in the secondary conductors to cause rotation, at the cost of an increase in the magnetizing current and the leakage reactance.

The flux common to both and set up by the resultant of the primary and secondary magnetomotive forces is the link of mutual influence between the primary and secondary. This influence manifests itself as electromotive forces set up in proportion to the effective number of turns, the flux, and the frequency in the circuit in question. (Of course, this is rigorously true only with the usual assumptions of sine wave distribution, etc.)

The torque is proportional to the summation of the products of the secondary turns, and the components of current in phase with the common flux of each, and to the common flux.

The usual theory of the induction motor takes into account only the phenomena within the motor itself, performance with adjustable external secondary resistance being analyzed by considering it to be merely an addition to the normal resistance of the secondary.

In Fig. 1, we reproduce a circle diagram, a vector diagram for analyzing induction motor performance, which lends itself to the introduction of electromotive forces etc., of concatenated machines.

$A H = I_1$ (proportional to primary current) represents the flux linking primary and secondary which would be produced by the primary current alone. (Saturation neglected)

$H I = C_1 I_1$ represents primary leakage flux.

$H G = I E = I_2$ (proportional to the secondary current) represents the flux linking secondary and primary which would be produced by the secondary current alone. (Saturation neglected)

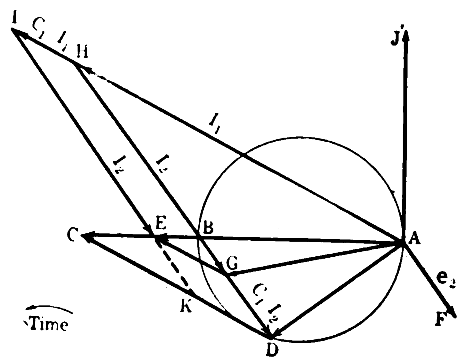

FIG. 1—THE CIRCLE DIAGRAM OF AN INDUCTION MOTOR

$G D = C_2 I_2$ represents secondary leakage flux.

$A E$ is thus the resultant of all the primary flux and that secondary flux, linking the primary, so that neglecting primary resistance drop, E is a fixed point for constant line voltage and frequency, as $A E$ is the flux which generates the counter e. m. f. to balance the applied voltage e_1.

$H G$ intersects $A E$ at B, and as

$$A B / A E = \frac{I_1}{I_1 (1 + c_1)},$$

we see that $A B$ is constant, making B also a fixed point. $A D$ is resultant of I_1 and $I_2 + C_2 I_2$ and therefore generates all secondary electromotive forces ex-

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cept resistance drop, which is, therefore in phase opposition to the voltage e_2, set up in the secondary in quadrature to flux $A D$. This makes $A F$ parallel to $H D$ and to $I E$ and further makes $A D H$ a right angle, which taken in connection with the fact that, as shown above, A and B are fixed points, demonstrates that the curve traced by point D is the arc of a circle.

A line parallel to $A I$ from point D intersects prolongation of $A E$ at C and prolongation of $I E$ at K.

$$\underline{C D} = C K + K D$$

$$\frac{C K}{E K} = \frac{A I}{I E}$$

$$C K = \frac{C_2 I_2 \times I_1 (1 + C_1)}{I_2} = I_1 C_2 (1 + C_1)$$

$K D = H I = C_1 I_1$ (since they are parallels intercepted by parallels)

$$\underline{C D} = I_1 [C_1 + C_2 (1 + C_1)]$$

$$\underline{B D} = B G + G D$$

$$\frac{B G}{E G} = \frac{I E}{I A}$$

$$B G = \frac{E G \times I E}{I A} = C_1 I_1 \times \frac{I_2}{I_1 (1 + c_1)} = I_2 \times \frac{C_1}{1 + C_1}$$

$$G D = C_2 I_2$$

$$\underline{B D} = I_2 \left(C_2 + \frac{C_1}{1 + C_1} \right) = \frac{I_2}{1 + C_1} \times (C_1 + C_2 (1 + C_1)$$

$E A$ is the flux whose counter e. m. f. balances all the applied line voltage as noted above. Let it be designated I_m. $B A$ is the *mutual flux* at running light and, if denoted by I_0, we have $I_0 = \frac{C_1}{1 + C_1}$.

$$C B = C E + E B$$

$$\frac{C E}{E A} = \frac{E K}{E I}$$

$$C E = E A \times \frac{E K}{E I} = I_m \times \frac{C_2 I_2}{I_2} = I_m C_2$$

$$\frac{E B}{E A} = \frac{I H}{I A} \qquad E B = I_m \times \frac{C_1 I_1}{I_1 (1 + C_1)} = I_m \times \frac{C_1}{1 + C_1}$$

$$C B = I_m \left(C_2 + \frac{C_1}{1 + C_1} \right) = \frac{I_m}{1 + C_1} \times [C_1 + C_2 (1 + C_1)] = I_0 [C_1 + C_2 (1 + C_1)]$$

Further, C is a fixed point since:

$$\frac{C E}{E A} = \frac{E K}{E I} = \text{Constant} = C_2 \times I_2 / I_2$$

$$C A = E A + C E = I_m + I_m C_2 = I_m (1 + C_2) = \frac{I_m (1 + C_2) [C_1 + C_2 (1 + C_1)]}{C_1 + C_2 (1 + C_1)}$$

Summing up we have:

$$C D = I_1 [C_1 + C_2 (1 + C_1)]$$

$$D B = \frac{I_2}{1 + C_1} \times [C_1 + C_2 (1 + C_1)]$$

$$C B = \frac{I_m}{1 + C_1} \times [C_1 + C_2 (1 + C_1)] = I_0 [C_1 + C_2 (1 + C_1)]$$

$$C A = \frac{I_m (1 + C_2)}{C_1 + C_2 (1 + C_1)} \times [C_1 + C_2 (1 + C_1)]$$

$$E A = I_m$$

$$B A = I_0$$

With proper scale, I_m could be made to represent the magnetizing current for a total flux I_m, (which is the quantity commonly calculated, as the primary reactance and resistance drop are usually omitted) I_0 could be made to represent the true running light current, primary reactance drop considered, I_1 the primary current and I_2 the secondary current. If we now change the scale of the diagram by the factor $C_1 + C_2 (1 + C_1)$, we may say that magnetizing i_m divided by $1 + C_1$ equals $C B$, equals true running light current i_0; primary current i_1 equals $C D$; secondary current divided by $1 + C_1$ equals $D B$.

A standstill, with zero secondary resistance $A D$, the resultant secondary flux must, of course, be zero, as its generated voltage is zero, which means that D coincides with A and $C D = C A$, so that we have the ideal short-circuit or standstill current with zero secondary resistance equal to $C A$.

As $C_1 I_1$ is defined as primary leakage flux, the primary reactance drop with current i_m is $C_1 e_1$, since i_m produces a total flux whose e. m. f. is equal to e_1. The primary reactance drop is further equal to $i_m X_1$ if X_1 be the primary reactance, thus:

$$C_1 e_1 = i_m X_1$$

$$C_1 = \frac{i_m X_1}{e_1}, \text{ and similarly,}$$

$$C_2 = \frac{i_m X_2}{e_1}$$

Thus, to draw the diagram of the motor, we need to know the primary and secondary reactances X_1 and X_2 and the nominal magnetizing current i_m. We need then only so much of Fig. 1 as is shown in Fig. 2.

Having chosen a scale, lay off:

$C B$ equal to i_m

$$C A \text{ equal to } \frac{i_m (1 + C_2)}{C_1 + C_2 (1 + C_1)} \text{ and}$$

draw a circle with $B A$ as diameter. $C M$ is the in phase or watt component of input current for any considered load. $M D$ parallel to $C A$ then locates D and the remainder of the diagram. The primary current is then $i_1 = C D$ and the secondary current i_2 is then $(1 + C_1) D B$, or if we use as the unit for i_2 the unit denoting the other currents divided by $1 + C_1$, we can let $D B = i_2$.

To find the secondary voltage $e_2 = A F$, we can first determine its value reduced to full frequency. The voltage generated by flux $A E$ of Fig. 1 is e_1, and that generated by $A B$ is, therefore, $\frac{e_1}{1 + C_1}$. So in Fig. 2, knowing e_1, we can say that $A B$ units of

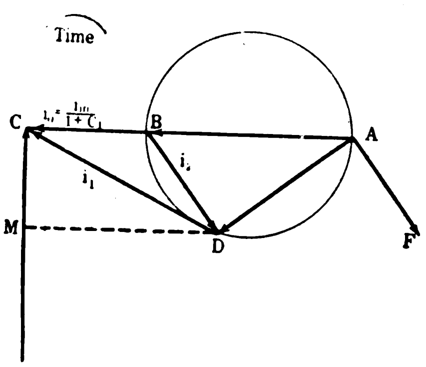

Fig. 2—Simplified Diagram

length correspond to $\frac{e_1}{1 + C_1}$ volts, and can regard $A B$ etc. as measures of voltage. So $A D$ is $\frac{A D}{A B}$ times $\frac{e_1}{1 + C_1}$ volts at standstill frequency. If the secondary resistance is known, the actual value of secondary induced voltage e_2 is, of course, $i_2 r_2$, so that per cent slip is $s = \frac{i_2 r_2}{A D}$.

"Synchronous watts" torque is $B D$ times $A D$, output is $(1 - S) B D \times A D$, efficiency $(1 - S) B D \times \frac{A D}{e_1} M C$, power factor $\frac{M C}{C D}$

If the ratio of secondary turns to primary turns is other than 1 to 1, the diagram is, of course, of necessity drawn for all factors reduced to either primary or secondary terms, secondary terms being usually used for work of the present sort. Thus, the primary voltage to be expressed in terms of secondary must, of course, be multiplied by ratio of secondary to primary effective terms, primary reactance by the square of this ratio, etc.

In the demonstration of Figs. 1 and 2, it was pointed out that point D traces the arc of a circle whose diameter is $B A$, because $A D B$ is a right angle, due to the phase opposition of e_2 and $i_2 r_2$ when the only e. m. f. in the secondary circuit, other than that induced by the total secondary flux, is resistance drop. If, as in Fig. 3, another e. m. f. than the resistance drop as

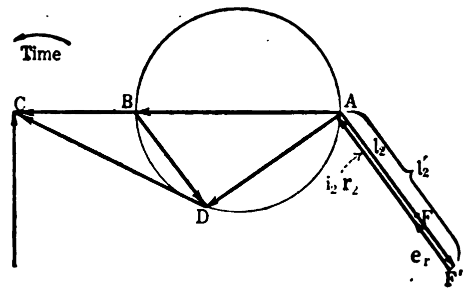

Fig. 3—Induction Motor Diagram
With regulating voltage e_r introduced into secondary in phase opposition with total induced e. m. f.

e_r be introduced, then D will still trace the circle with the diameter $A B$ when and only when the introduced e. m. f. is in phase with or in phase opposition to e_2. In this case, for given values of i_1, i_2 etc., e_2 must be equal and opposite to the algebraic sum of $i_2 r_2$ and the introduced voltage; hence, since the inducing flux of e_2 is determined by the currents,—its inducing frequency and the slip and speed must follow variations in the algebraic sum of $i_2 r_2$ and the introduced voltage.

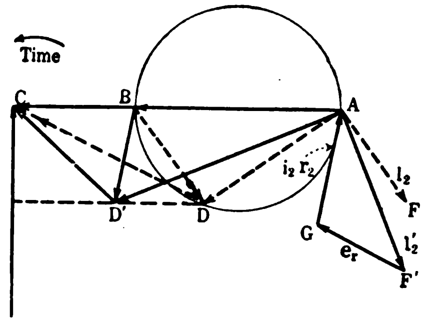

Fig. 4—Induction Motor Diagram
With regulating voltage e_r introduced into secondary out of phase with total induced e. m. f.

It is, therefore, evident that varying the introduced voltage, while maintaining it in phase with e_2 gives a means of varying the speed of the motor without effecting its power factor torque etc.

If now, as in Fig. 4, the introduced e. m. f., e_r be of different phase from that of e_2, point D departs from the circumference of the circle whose diameter is $B A$, as shown at D^1 because i_2 is no longer in phase opposition to e_2, hence, $A D^1 B$ is no longer a right angle. It is seen that in addition to regulating the speed, the power factor of the motor may also be

regulated by proper selection of phase as well as magnitude of the introduced e. m. f.

It is clear, of course, that the frequency of the introduced or regulating e. m. f. must at all times be exactly that of e_2, in order to maintain the phase relation shown.

Thus, if we can introduce at exact secondary frequency a regulating voltage of controllable phase

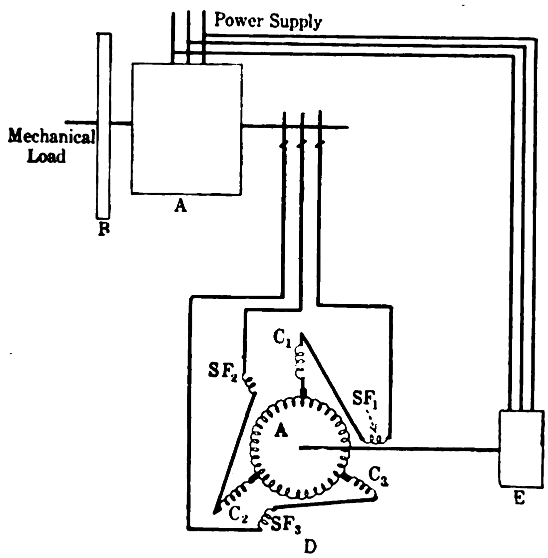

Fig. 5—Neutralized Series-Excited Three-Phase A-C. Commutator Machine and Connections for Automatic Single-Range Regulation of Induction Motor Equipped with Flywheel to Reduce Peaks on Line

with respect to e_2 and controllable magnitude, we shall be able to regulate either speed, power factor or both.

Single-Range, (Below Synchronism Only) Speed and Power Factor Control by Means of a Constant-Speed, Series Commutator Motor

In Fig. 5, we show schematically at D, a three-phase series neutralized commutator machine whose terminals are connected to the secondary slip rings of main motor A. The speed of D is held practically constant by generator E.

Neutralizing winding C_1, C_2, C_3 balances the armature reaction (magnetomotive forces) of armature A, and so of necessity neutralizes the e. m. fs. set up in A by the transformer action of the fluxes induced by series exciting windings $S\,F_1$, $S\,F_2$, $S\,F_3$. (C_1, C_2, C_3 being in series with A carry the same currents as A, hence, for a balanced condition of magnetomotive forces must have an equivalent and opposite number of turns, so the e. m. fs. also cancel). Thus the e. m. fs. appearing at the terminals of D are the leakage reactance drop, resistance drop and the rotation e. m. f. induced by the rotation of the armature A. The rotation e. m. f. is, of course, proportional to the flux and the speed of rotation, the flux, neglecting saturation being proportional to the main currents which flow through series exciting windings $S\,F_1$, $S\,F_2$, $S\,F_3$. This arrangement can then be seen to be such that the speed of A will be reduced with the increase of load, provided the rotation voltage, as e_r in Figs. 3 and 4, be given a suitable component in phase with the resistance drop, thereby having the same effect on the main motor speed, as increasing the resistance.

Up to the point of the magnetic saturation, two laws may be seen to inhere in the machine D.

1. The flux, hence, the rotation voltage at constant speed, is proportional to the current.

2. The phase angle between the current and the rotation voltage (hence, the angle between resistance drop and rotation voltage) is constant, (it can only be changed by changing the construction of the machine).

These are the basis of the circle diagram of Fig. 6:

Points A, B and C are determined exactly as in Fig. 1, except that for X_2 we now substitute X_{2+c+c_s} where $X_{2+c+c_s} = X_2 + X_c + X_{c_s}$ and X_c = leakage reactance of regulating motor at primary frequency

$$X_{c_s} = \frac{\text{kv-a. required to excite regulating motor}}{i_2^2 \times \sqrt{3}}$$

The kv-a. is at primary frequency and unsaturated iron of regulating motor is assumed. Obviously the performance of an induction motor is not changed for our purposes, having a part or all of the rotor leakage

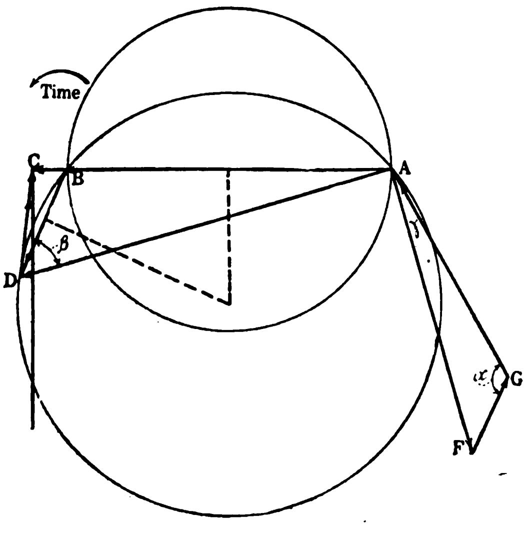

Fig. 6—Circle Diagram of Induction Motor with Constant-Speed Series Commutator Regulating Machine

reactance external to the machine. Angle $\alpha = F\,G\,A$, between resistance drop $F\,G$ and rotation e. m. f. $G\,A$ is constant by law No. 2, and $G\,A$ is by law No. 1 proportional to $B\,D$ and hence to $F\,G$. For these reasons angle $G\,F\,A$ is constant and since angle $B\,D\,A = 90$ deg. $-$ angle $G\,F\,A$, we see that β = angle $B\,D\,A$ is also constant.

Thus, as A, B, and C are fixed points, point D traces a circle whose center must be at the intersection of the perpendicular bisectors of $A\,B$ and $B\,D$.

We have remarked that Figs. 1, 2, 3, 4 and 6 are

rigorous when and only when the iron of the machine is unsaturated, that is, when the flux may be regarded as proportional to the ampere turns. This condition is closely enough approximated in the main induction motor so that saturation may be neglected without much loss of accuracy. For the series machine of Fig. 6, however, to be of economical proportions, considerable saturation will be attained within the working range; hence, it becomes desirable to investigate its effects. In Fig. 7, A, B, C has been determined as was done for Fig. 6, and $B\,D\,A$ is the corresponding circle determined by angle $B\,D\,A$, which is determined by ratio $\frac{A\,G}{F\,G}$ and design angle α, saturation neglected.

Now with current $B\,D$, we can calculate a new value

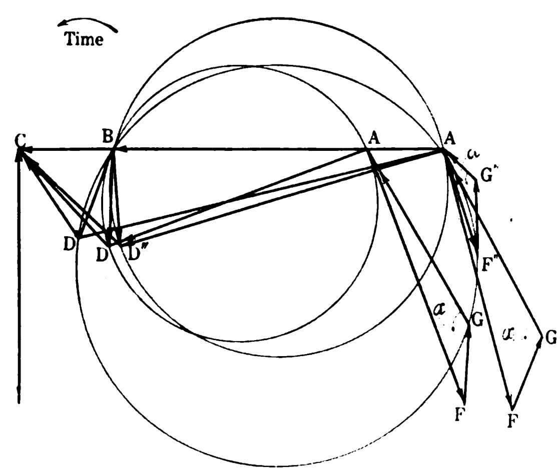

FIG. 7—DIAGRAM OF INDUCTION MOTOR AND CONSTANT-SPEED SERIES COMMUTATOR REGULATING MACHINE

Taking account of saturation of iron of regulating machine.

for X_{2+c+c_s} which will hold only for this one current, since in expression

$$X_{c_s} = \frac{\text{kv-a. to excite regulating motor}}{i_2^2 \times \sqrt{3}}$$

we can determine kv-a. (at full frequency, of course) from the known or assumed magnetizing curve of the regulating machine. With this new (and decreased) value of X_{2+c+c_s} we calculate $A^1\,C$ instead of $A\,C$. If the new value of X_{2+c+c_s} were constant, our new circle would be $B\,D^1\,A^1$, but as it varies, D^1 may be the only load point upon it. Triangle A^1, F^1, G^1 is, of course, equal to triangle $A\,F\,G$, and angle $B\,D^1\,A^1$ is equal to angle $B\,D\,A$.

A second effect of the saturation is that the ratio of rotation e. m. f. to field current (field current being the same as the main current for a series machine) is reduced, so considering this, $A^1\,G''\,F''$ is the e. m. f. triangle with angle $A^1\,G''\,F''$ still equal to angle $A\,G^1\,F^1$ and $A\,G\,F$.

Since $A^1\,G''$ is less than $A^1\,G^1$ and $G''\,F'' = G^1\,F^1$ with constant α we see that angle $G''\,F''\,A^1$ is less than angle $G^1\,F^1\,A^1$, hence, angle $B\,D''\,A^1$ greater than angle $B\,D^1\,A^1$ and the circle if X_{2+c+c_s} and $\frac{A\,G''}{G''\,F''}$ were constant would be $B\,D''\,A^1$.

We thus see that the two effects of saturation of the regulating machine partially offset one another, as the reduction of X_{2+c+c_s} makes the imaginary circle larger and the power factor more leading, while the reduction of ratio $\frac{A^1\,G^1}{G^1\,F^1}$ to $\frac{A^1\,G''}{G''\,F''}$ makes the imaginary circle smaller and the power factor more lagging.

The point D'' cannot be located by rule and compass unless we calculate triangles $A^1\,D''\,B$ and $A^1\,F''\,G''$ which can be done as follows:

$A^1\,G''$, $G''\,F''$ and angle $A^1\,G''\,F''$ are known.

$$A^1\,F'' = \sqrt{\overline{A^1\,G''}^2 + \overline{G''\,F''}^2 - 2 \times A^1\,G'' \times G''\,F'' \times \cos A^1\,G''\,F''}$$

$$\operatorname{Sin} A^1\,F''\,G'' = \frac{A^1\,G'' \times \sin A^1\,G''\,F''}{A^1\,D''}$$

Angle $F''\,A^1\,G''$

$$= 180\text{ deg.} - (\text{angle } A^1\,F''\,G'' + A^1\,G''\,F'')$$

determining triangle $A^1\,F''\,G''$.

In triangle $B\,D''\,A^1$, $B\,A^1$ and $B\,D''$ are known and angle $B\,D''\,A^1 = 90$ deg. $-$ angle $A^1\,F''\,G''$.

$$\operatorname{Sin} B\,A^1\,D'' = \frac{B\,D'' \times \sin B\,D''\,A^1}{B\,A^1}$$

Angle $D''\,B\,A^1$

$$= 180\text{ deg.} - (\text{angle } B\,A^1\,D'' + \text{angle } B\,D''\,A^1)$$

$$A^1\,D'' = \frac{B\,D'' \times \sin D''\,B\,A^1}{\sin B\,A^1\,D''} \quad \text{or} \quad \frac{A^1\,B \sin D''\,B\,A^1}{\sin B\,D''\,A^1}$$

Knowing, thus, $A\,D''$ and $B\,D''$, we can find point D'' with compass.

We can now construct the curve traced by D'' by assuming values of current $B\,D''$, calculating for each value $A^1\,B$, $A^1\,G''$ and $A^1\,D''$ as described.

For the designs ordinarily encountered, this yields a curve so closely approximating for the working load the original circle $B\,D\,A$ in which saturation is neglected, that it is not necessary to go beyond the construction of $B\,D\,A$ to get a good idea of the characteristics except slip which is $\frac{A^1\,F''}{A^1\,D''}$. If the scale used for $A^1\,F''$ is not that of $A^1\,D''$, then, of course, slip is $\frac{A^1\,F''}{A^1\,D''}$ multiplied by the proper ratio of scales.

The combination in Fig. 5 is suitable to service in which there are rapid and wide fluctuations in load which it is desired to absorb as much as possible by the flywheel B. This arrangement is superior to the use of a resistance across the slip rings because instead of being wasted as in the resistance, the slip energy

can all be returned to the power system except for the machine losses of D and E. When applied to a motor with secondary resistance the flywheel reduces the peak loads by delivering torque as it is retarded. The return of most of the slip energy to the line by the regulating set decreases the peak loads still more. A further advantage for the regulating set is the means which it affords of materially improving the power factor of the main motor.

Single-Range (Below Synchronism Only), Speed and Power Factor Control by Means of a Constant-Speed, Shunt Commutator Motor

The series regulating set is, of course, the simplest form, but it is not adjustable without tapping the field winding or external apparatus, and as it imparts to the main motor the characteristic of a material reduction of speed with the assumption of load, it is not suited to the majority of industrial uses in which variable speed from large induction motors is required. In the greater number of cases, it is desired to adjust the speed to a value suited to the momentary requirement of the process, and have the speed remain at approximately the adjusted value irrespective of load variation.

The total induced secondary e. m. f. of an induction motor including the secondary reactance drop is proportional to the "rotor field" (See A D of Fig. 1) and the slip. So, as is well appreciated, within the working range the slip is about proportional to the torque as the torque is about proportional to the rotor current, the current being proportional to the total induced rotor voltage. If at a given load we obtain speed reduction by an increase in resistance or by the use of a "series" regulating set, in which cases an increase in secondary induced e. m. f., hence, slip is required to overcome the additional resistance drop, or the rotational e. m. f. of regulating set, plus resistance drop, then, as soon as the load disappears, the main motor speeds up to synchronism, since the secondary resistance drop and the rotational e. m. f. of the regulating motor vanish with the current. If the rotational e. m. f. of the regulating motor could be made independent of the load and of the slip, then with the departure of load it would remain constant, so that the speed would only rise enough to make the total induced secondary e. m. f. equal to the rotational voltage of the regulating motor, leaving no resultant to circulate load current. With load fluctuations, the speed would then fluctuate by only such small amounts as to cause at all times the small difference between total induced secondary e. m. f. and the rotational e. m. f. of the regulating motor to overcome the small resistance drop of the windings; usually only a few per cent of synchronous speed.

In Fig. 8 is shown an arrangement to approximate these conditions. "A" is the main motor, "D" a neutralized three-phase shunt commutator motor, whose speed is held practically constant by generator E, returning the energy derived from D to the line. "B" is an auto transformer excited from the slip ring circuit and provided with suitable taps to apply predetermined percentages of the slip ring e. m. f. to the shunt exciting windings F_1, F_2, F_3. Assume that the resistance drop in the F_1, F_2, F_3 circuit is negligible and that "B" applies to F_1, F_2, F_3 the selected percentage of the total secondary induced e. m. f. This with the further assumption that the reactance drop of the regulating motor is included in the slip ring e. m. f. (which is supplied to "B") and that the resistance drop of the main motor rotor is not included in the slip ring e. m. f., will give what may be termed for our purposes, "pure shunt excitation." The effects of

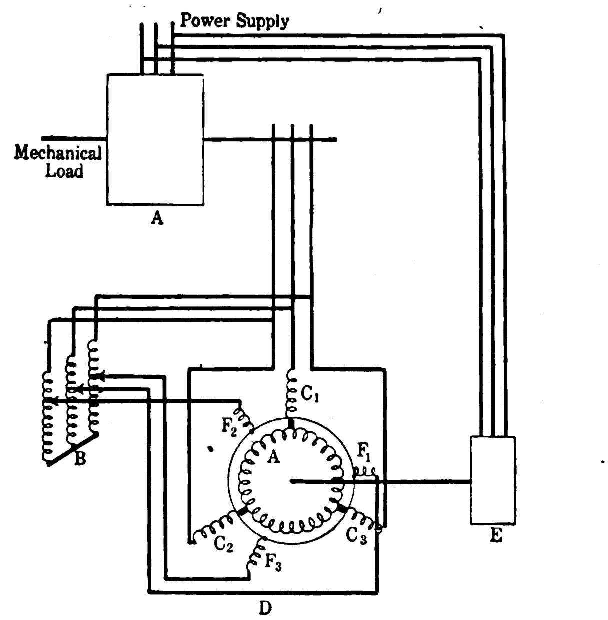

Fig. 8—Neutralized Three-Phase Shunt Constant-Speed A-C. Commutator Machine and Connections for Adjustable-Speed Control of Induction Motor below Synchronism

these assumptions will be pointed out later. The counter e. m. f. of F_1, F_2, F_3 thus consists of the e. m. f. set up by the flux excited by it, and is, therefore, proportional to the flux and the frequency (frequency itself being proportional to slip s).

$$i.\,e.,\quad e_f = k \times \phi \times s$$

The e. m. f. applied to the field is proportional to the total induced e. m. f., as remarked above, and the total induced e. m. f. is equal to its own standstill value for the main motor current (hence torque) in question times the slip, so we see that,

total induced e. m. f. at standstill $\times\, s = k \times \phi \times s$.

ϕ is thus independent of frequency and proportional only to total standstill induced e. m. f. Referring to Fig. 9, A, B, C is constructed exactly as Fig. 1, including the leakage reactance of the regulating motor with that of the secondary of the main motor, so that instead of X_2, we shall have $X_{2+c} = X_2 + X_c$ and

instead of C_2, we shall have C_{2+c}. The circle B, D, A would thus apply with regulating set D and E of Fig. 8, stationary. With the regulating set running, we get secondary current $B\,D^1$, total induced e. m. f., $A\,F$ of main motor secondary proportional to slip and to $A\,D^1$ and rotation e. m. f. of regulating motor $A\,G$ proportional to $A\,D^1$ and at a constant angle γ from $A\,F$, angle γ being determined by the connections of the transformer B and exciting winding F_1, F_2, F_3 of Fig. 8.

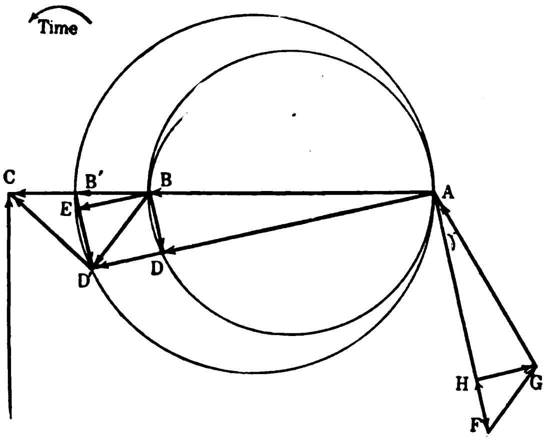

Fig. 9—Circle Diagram of Induction Motor and Pure Shunt Excited Constant-Speed Commutator Machine

Resolve resistance drop $F\,G$ into the component $F\,H$ in phase opposition to $A\,F$ and $H\,G$ in quadrature to $A\,F$, the corresponding components of secondary current $B\,D^1$ being $B\,D$ and $D\,D^1$.

$D\,D^1$ is proportional to $H\,G$, $H\,G = A\,G \sin \gamma$, so $H\,G$ is proportional to $A\,G$ (γ constant) which is proportional to $A\,D^1$, hence, $D\,D^1$ is proportional to $A\,D^1$.

$A\,D = A\,D^1 - D\,D^1$, hence, $A\,D$ is proportional to $A\,D^1$.

$B\,D$ and $B^1\,D^1$ are both perpendicular to $A\,D^1$, hence,

$\dfrac{A\,B^1}{A\,B} = \dfrac{A\,D^1}{A\,D}$ = constant, and B^1 is fixed point.

So curve traced by D^1 is a circle.

Slip "s" is equal to $\dfrac{A\,F}{A\,D^1}$.

At running light (zero torque) $B\,D$ and $H\,F$ become zero. (For proof of this see Fig. 1. The torque of the motor is proportional to the mutual flux $A\,G$ and the component of secondary current in quadrature with it. This is the same thing as the total secondary current and the component of the mutual flux in quadrature to the current, which component is equal to $A\,D$, the "rotor field." The torque is, therefore, zero when $B\,D$ is zero, and in Fig. 9, $B\,D$ is the torqe producing component of $B\,D^1$.)

Thus, running light slip $s_0 = \dfrac{A\,H}{A\,D^1}$, and the additional slip s_1, due to the load is thus, $\dfrac{H\,F}{A\,D^1}$.

It is thus seen that at running light the main motor runs at slip s_0, determined by the angle γ, and the ratio $\dfrac{A\,G}{A\,D^1}$, which conditions are adjusted by the connections at B, Fig. 8. The load slip s_1 is the same for all values of s_0, provided angle γ be so chosen that $\dfrac{H\,G}{A\,D^1}$ remains constant, and is the same as would obtain for a normal motor whose circle is $B^1\,D^1\,A$ and whose short-circuited secondary has the resistance corresponding to the current $B^1\,D^1$ and the drop $H\,F$. Thus it is evident that the main motor, regulated as in Figs. 8 and 9 would retain practically the same load slip-torque, power factor-torque and input-torque characteristics as with short-circuited slip rings, but would have no-load speeds equal to the synchronous speed $\times \dfrac{1 - s_0}{1}$.

It will be noted from Fig. 9 that the primary power factor can readily be improved and that at the same time the pull-out torque of the main motor can be increased.

Single-Range (Below Synchronism Only) Speed and Power Factor Control by Means of a Constant Speed, Compound Excited Commutator Motor

Occasionally, in processes where the peak loads are high and of brief duration and of sufficient magnitude

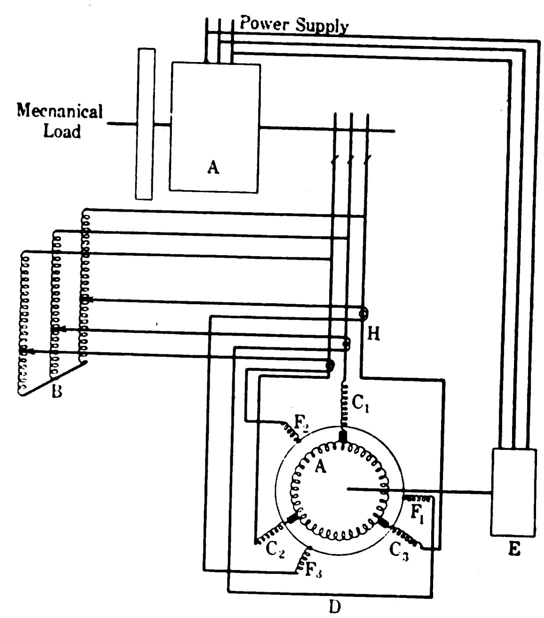

Fig. 10—Neutralized Compound-Excited Constant-Speed Three-Phase A-C. Commutator and Connection for Adjustable-Speed Single-Range Speed Control of Induction Motor Giving Automatic Drop in Speed With Increase of Load.

in proportion to the capacity of the supply system to be objectionable, it becomes desirable to have a larger drop in speed due to load than would be obtained with a shunt commutator motor, so that a fly-wheel can be

effectively added to smooth out the peak loads, and at the same time retain the adjustability of the speed. Fig. 10 illustrates a method of compounding the regulating motor.

In the shunt excitation, neglect the same factors as in the case of the shunt regulating motor, (the secondary resistance drop of the main motor and the absence of the reactance drop of the regulating motor). In order to get the compounding action it would not do merely to put in some series turns as in a d-c. machine, since there is applied to the shunt field a fixed percentage of the total induced secondary e. m. f., which means a flux proportional to the rotor field of the main motor as already pointed out. Thus, the ampere turns of the

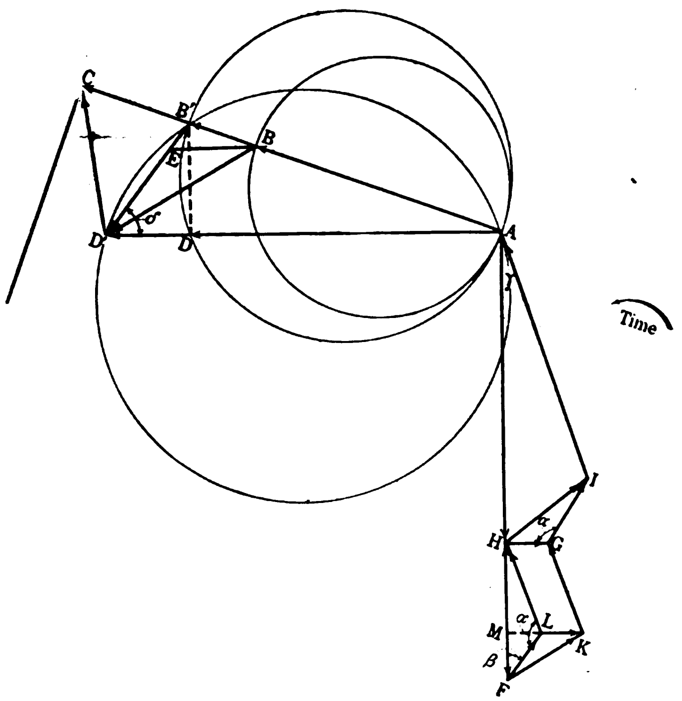

FIG. 11—CIRCLE DIAGRAM OF INDUCTION MOTOR WITH COMPOUND-EXCITED CONSTANT-SPEED A-C. COMMUTATOR REGULATING MACHINE

series winding would merely be balanced by a change in the shunt current, F_1, F_2, F_3 serving as the primary of a transformer. It, therefore, becomes necessary to change the field voltage in response to load, in order to change the flux and hence the rotation e. m. f. This is done by the series transformer H, which has an air gap in the magnetic circuit, so that its flux is proportional to the resultant of the primary and secondary ampere turns. Of course, a proportionate effect upon the flux of the regulating motor, will accompany any changes in the flux in the series transformer (slip transformer) since the alteration in flux produces a proportionate alteration in voltage applied to regulating motor field, and this in turn a proportionate change in flux thereof. This then means that the rotation e. m. f. will contain a component proportional to the resultant ampere turns of the series transformer, which component, of course, may itself be resolved into components corresponding to the components of the resultant ampere turns of the series transformer.

The performance of the motor, controlled as shown in Fig. 10, is illustrated in Fig. 11, in which A, B and C are again found as for Fig. 1, including the reactance of machine D with that of the secondary of A. B is the no-load point, such that $B\,B^1$ is the no-load secondary current, and D^1 is the load point under consideration. Resolve secondary current $B\,D^1$ into component $B\,E$ parallel to $A\,D^1$ and $E\,D^1$ part of $B^1\,D^1$. Component $B\,E$ produces no torque. $I\,A$ is the rotational e. m. f. of regulating motor at constant angle from total induced secondary e. m. f. $A\,F$ of main motor and bearing constant ratio to $A\,D^1$ being due to the application of total induced e. m. f. $A\,F$ to the shunt field circuit of D, Fig. 10. $H\,G$* is resistance drop of $B\,E$ and $I\,G$ is the rotation e. m. f. produced by D of Fig. 10 by the voltage introduced into the field circuit by the existance of current $B\,E$ in primary of H. The angle α $(I\,G\,H)$ is determined by design and is, of course, constant, as is the ratio $\dfrac{G\,I}{H\,G}$.

$F\,K$ is total resistance drop, and $F\,L$ and $L\,K$ are components, due to $E\,D^1$ and $B\,E$. $K\,G = L\,H$ is compounding effect, due to $E\,D^1$, just as $G\,I$ is due to $B\,E$, so angle $H\,L\,F$ = angle $I\,G\,H = \alpha$ and is constant. Further $\dfrac{H\,L}{L\,F}$ is constant, so angle $L\,F\,H = \beta$ is constant and as $F\,L$ is parallel to $B^1\,D$ and $A\,F$ is perpendicular to $A\,D^1$, angle $B^1\,D^1\,A = \delta = 90$ deg. $- \beta =$ constant.

Therefore, D_1 traces the arc of a circle.

The slip S is equal to $\dfrac{A\,F}{A\,D^1}$ and at running light (zero torque) $E\,D^1$, $F\,L$, $H\,L$ and $K\,G$ become zero $\dfrac{A\,I}{A\,D^1}$ and angle γ are constant. Angles of triangle $I\,H\,G$ being constant and $G\,H\,A$ being 90 deg., we see that $I\,H\,A$ is also a constant angle, hence angle $A\,I\,H$ is constant. So $\dfrac{A\,H}{A\,D^1}$ is constant and as this is the expression for S_0, the running light slip where $H\,F$ is zero, we see that the slip, due to load $S_1 = \dfrac{H\,F}{A\,D^1}$, consisting of $L\,F$, due to the resistance and $H\,L$, due to the compounding action of the slip transformer. We thus see that the running light slip S_0 is adjustable by means of B in Fig. 10, while the load slip S_1 has been increased from $\dfrac{M\,F}{A\,D^1}$ to $\dfrac{H\,F}{A\,D_1}$ by the slip trans-

*Point H is on $A\,F$ because at zero load $B\,E$ becomes $B\,B'$, the total secondary current and $H\,G$ and $G\,I$ the only e. m. fs. to close the gap between $I\,A$ and $A\,F$. As $B\,H$ is proportional to $A\,D'$ and hence $A\,I$ and at constant angle thereto, H must remain on $A\,F$.

former. Further, it is apparent that by controlling the angle α we can make the power factor get more leading or more lagging as load comes on, and thus also, increase or decrease pull-out torque of the motor.

In defining the conditions assumed for Fig. 10, we mentioned that the leakage reactance drop of the regulating motor was supposed to be included in the voltage applied to the exciting winding. The actual effect of excluding it from this circuit can now be shown in Fig. 11-A, a modification of part of Fig. 11. The reactance in the regulating motor is, of course, not applied to its field, and hence the actual rotation e. m. f. for shunt excitation should not include $I^1 I$, the rotation e. m. f., due to the application of reactance drop

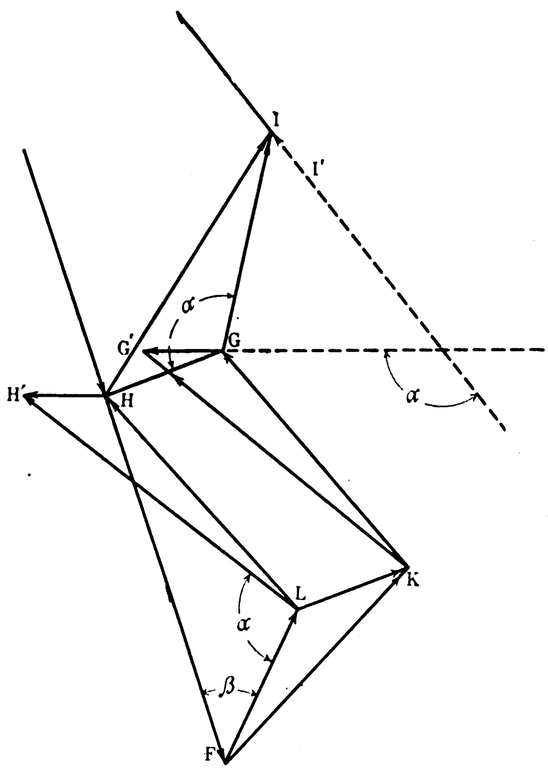

Fig. 11-a—Effect on Fig. 11 of Correctly Locating Resistance of Main Motor Secondary and Reactance of Regulating Machine

of $B E$ to the shunt field. Note that $I^1 A$ is the rotational e. m. f. of pure shunt excitation, and that as triangle $B E B^1$ is similar to triangle $A D^1 B^1$, $\dfrac{B E}{A D^1} = \dfrac{B B^1}{A B^1}$, hence $I^1 I$ is proportional to $I A$ and to $A D^1$ so that $A H$ is still proportional to $A D^1$. $G G^1$ and $H H^1$ are the rotational e. m. f., due to application of reactance drop of $E D^1$ to shunt field, and hence proportional to $E D^1$, so they may be excluded from $K G^1$ and $L H^1$, and for them may be used instead, $K G$ and $L H$. As angle $G^1 G K$ and $H^1 H L$ are fixed and as $H H^1$ and $G G^1$ are proportional to $H L$ and $G K$, we see at once that $H L$ is proportional to $L F$, angles $H L F$ (= angle $H L H^1 + \alpha$) and $H F L$ are constant, hence, $\delta = B^1 D^1 A = 90$ deg. $- \beta$ is constant and D_1 still traces a circle.

Thus when we consider the actual effect of the leakage reactance of the regulating motor we see that it is merely to alter the amount of compounding. Hence, to consider this in the case of Fig. 9, would mean to change it to a diagram like Fig. 11, with a small amount of compounding, the "pure shunt excitation" being only a hypothetical condition.

The magnetizing current of the regulating motor has so far been neglected. Neglecting regulating motor saturation, this is proportional to and in phase with $A D^1$ of Fig. 11. As it flows through the armature and compensating windings of the regulating motor only, its reactance drop can be added to the compounding just as was done in Fig. 11-A at $I I^1$ and its resistance drop, proportional to $B E$ can be added to the resistance drop of $B E$. Thus, we still would get our circle diagram. However, it does not usually pay to consider so small an element except as an interesting theoretical consideration.

The effect of the inclusion of the main motor resistance drop in the voltage applied to the regulating motor field of Figs. 8 and 9 may be treated similarly, providing we confine ourselves to operation so far from synchronism and at such a range of loads, that s_1 is a fairly small part of s_0, in which case the component of rotation e. m. f. caused by the resistance drop is approximately proportional to the current components.

Further the accuracy of the diagram developed so far hinges on the assumption that the values of S (distance from synchronous speed) are so great as to cause the variations in the relative values of the resistance and reactance drops of the shunt field circuit to be relatively small, which will mean a small variation in $H G$ of Fig. 9, since variations in the phase relation of field current and "total induced e. m. f." $A D^1$ mean variations in angle γ. As the resistance drop is larger and larger compared to the reactance drop the smaller the slip and frequency, it therefore appears that Figs. 9 and 11 are accurate only at fairly large values of slip, and small ratios of resistance drop to reactance drop in the field circuit, becoming inaccurate as synchronism is approached. Consideration of these effects has lead the writer to the use of a constant voltage frequency changer and adjustable resistance for overcoming and regulating the resistance drop of the field circuit, and of an auto-transformer with taps (and alternative devices) for overcoming the reactance drop, leading in turn to a feasible way of regulating the main motor through and above its synchronous speed as well as below.

Double-Range (All Speeds Above or Below Synchronism) Speed and Power Factor Control by Means of a Constant-Speed Shunt Commutator Motor

Several advantages of regulating the main motor speed above as well as below its synchronous value

appear at once. The capacity of the regulating set for a given maximum speed variation and maximum speed is reduced 50 per cent, provided the synchronous speed of the main motor is half way between the extremes. For if, S_{max}, S_{min} and S_s represent the maximum, minimum and synchronous speeds of the main motor and $H\,P_{max}$ be the horsepower capacity at speed S_{max}, we have for single range,—

$S_s = S_{max}$ and capacity of set is:—

$$H\,P_{set} = H\,P_{max} \times \frac{S_{max} - S_{min}}{S_{max}}$$

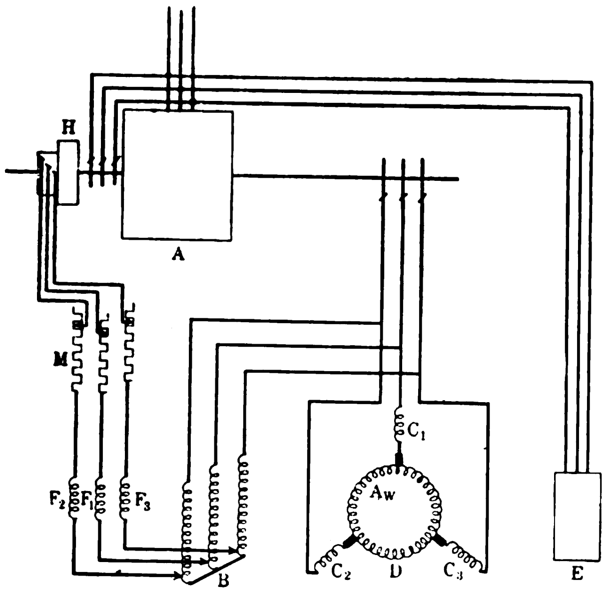

FIG. 12—NEUTRALIZED THREE-PHASE SHUNT A-C. COMMUTATOR MACHINE AND CONNECTIONS FOR ADJUSTABLE-SPEED CONTROL OF INDUCTION MOTOR FOR OPERATION BOTH ABOVE AND BELOW SYNCHRONISM.

Now for double range, as above, we have:—

$$2\,(S_{max} - S_s) = S_{max} - S_{min}$$

$$H\,P_{set} = H\,P_s \times \frac{S_{max} - S_s}{S_s} = \frac{H\,P_s}{S_s} \times \frac{S_{max} - S_{min}}{2}$$

But as $\frac{H\,P_s}{S_s} = \frac{H\,P_{max}}{S_{max}}$ we have,—

$$H\,P_{set} = 1/2\,H\,P_{max} \times \frac{(S_{max} - S_{min})}{S_{max}}$$

showing that the capacity of the double-range set is one-half that of the single range. Thus, not only will the first cost be materially less, but the machine losses will also be greatly decreased.

A second important advantage is that the synchronous speed of the main motor is in the middle of the speed range, so that often times many processes may be carried out running as plain induction motor with the set shut down, with consequent saving of wear and tear on it.

The apparatus, shown in Fig. 12, is the same as Fig. 8, except that instead of going to a star point the ends of shunt field coils F_1, F_2, F_3 are carried through the adjustable resistance M, to the frequency changer H mounted upon the shaft and wound for the same number of poles as main motor A. This machine has a single primary winding connected to a commutator exactly as in the armature of a d-c. machine, and has collector rings tapped in at points 120 electrical degrees apart (for three-phase power). The secondary is a smooth laminated ring without windings which may or may not rotate with the primary. Obviously, a "revolving field" is set up in this machine, which at standstill, rotates at synchronous speed of A and H. With 120 electrical degrees brush spacing on the commutator, we get three-phase full frequency voltage of the same value as we apply to the collectors neglecting machine drop, and the phase relating between the commutator and collector currents depends upon the position of the brushes on the commutator. Assume A to rotate synchronously in opposite direction to the rotation of flux of H, which carries said flux backward mechanically at the same rate that it is turning electrically, leaving it stationary in space, and permitting H to produce direct current at commutator like a synchronous converter.

Thus, it is seen that H is automatically a source of constant voltage at exact slip ring frequency.

If we regulate A at no-load (for simplicity) we see that the rotation e. m. f. of D, hence both its flux and field current are proportional to slip S. Hence the reactance drop component of the impedance drop of the field circuit, being proportional frequency as well as flux is proportional to S^2 while the resistance drop is merely proportional to the field current and to S. By connecting to taps of B whose distance from the star point is proportional to S, we get a voltage proportional to S^2, since the total e. m. f. of B is itself proportional to S. By changing taps on resistance M so that the entire resistance of the circuit is proportional to $1/S$, we just permit constant voltage frequency changer H to supply the resistance drop balancing e. m. f., while auto-transformer B furnishes reactance drop balancing e. m. f. In practise, one set of switches can be arranged to vary both M and B simultaneously.

With M operating at a considerable distance from synchronous speed, the field resistance drop can be exactly balanced for a given load by H, so that as B supplies the reactance drop, the conditions previously assumed are attained. From Fig. 9 it will be noted that the phase of $A\,F$ alters with load, while that of the voltage from H in Fig. 12 remains fixed. This only introduces a comparatively small discrepancy for working loads, the main effect being a slight alteration of the load slip.

Let us now, on the other hand, consider the case of running near synchronism, where the reactance drop of

the field, varying as S^2, and very nearly balanced by B has become practically ineffective. Fig. 13 is the simplest circle diagram for these conditions, the constant excitation of D, Fig. 12, from the frequency changer H being so chosen that, in Fig. 13, rotational e. m. f. $H\,A$ is perpendicular to line $A\,B\,C$ found as usual. $A\,F$ is the total induced e. m. f. of main motor secondary, $F\,H$ the resistance drop in main secondary circuit for secondary current $B\,D^1$.

Resolve $F\,H$ into components $F\,G$ in phase opposition to $A\,F$ and $G\,H$ perpendicular to $A\,F$, and $B\,D^1$ into corresponding components $B\,D$ and $D\,D^1$, (Point

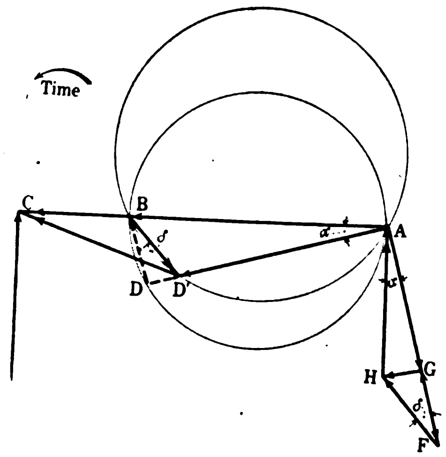

Fig. 13—Circle Diagram of Induction Motor Running below Synchronism with Regulating Machine Receiving Constant Shunt Excitation without No-Load Power Factor Improvement

D, thus traces the circle of the main motor with regulating motor reactance included, but with $A\,H$ left out of the circuit)

$$G\,H = H\,A \sin \alpha$$

$$F\,H = \frac{G\,H}{\sin \delta} = \frac{H\,A \sin \alpha}{\sin \delta}$$

$$B\,D = A\,B \sin \alpha$$

$$B\,D^1 = \frac{B\,D}{\cos \delta} = \frac{A\,B \sin \alpha}{\cos \delta}$$

Further, $$B\,D^1 = \frac{F\,H}{r_{2+c}}$$

So $$\frac{H\,A \sin \alpha}{r_{2+c} \times \sin \delta} = \frac{A\,B \times \sin \alpha}{\cos \delta}$$

And $$\tan = \frac{H\,A}{A\,B} \times \frac{1}{r_{2+c}}$$

As $H\,A$, $A\,B$ and r_{2+c} are constant,
Angle δ must be constant.

Angle $B\,D^1\,A$ is 90 deg. + δ, hence D^1 traces a circle.

In Fig. 14, we have given the excitation, and hence, the rotation voltage $A\,H$ a shift β from its position in Fig. 13, so as to improve the power factor.

Resolve the resistance drop $F\,H^1$, of the secondary current $B^1\,D^1$ (A, B^1 and C being the usual fixed points) into $H^1\,H$ perpendicular to $H\,A$ perpendicular to $A\,B$, and $F\,H$, corresponding current components being $B\,B^1$ and $B\,D^1$. Since $H^1\,A$ and angle β are constant, H and B are fixed points. Now resolve $F\,H$ into $F\,G$ along $A\,F$ and $G\,H$ perpendicular to $A\,F$, also $B\,D^1$ into corresponding components $B\,D$ and $D\,D^1$. D^1 may now be shown to trace arc of circle $B\,D^1\,A$ as in Fig. 13. We note the power factor and pull-out torque are better than for Fig. 13.

As we are considering operation at rather small values of slip where the shunt excitation is all from H and M of Fig. 12 and is not effected by B, we can compound by the use of plain series windings as with d-c. machines without interference by transformer action.

In Fig. 15, we have shown the effect of such compounding, brought about by making changes in the neutralizing winding C_1; C_2, C_3. It can be demonstrated that a polyphase armature turning above its own synchronous speed in the field, set up by its own reaction generates a rotation voltage leading the current by 90 deg. Hence, by weakening $C_1\,C_2\,C_3$, we can get this sort of compounding in any desired degree.

$A\,B^1\,C$ denote the usual fixed points of the main motor with reactance of regulating motor included. $H^1\,A$ is the fixed excitation from frequency changer and rheostat and $B^1\,B$ is running light secondary current, due to $H^1\,I$, $B^1\,D$ being load current considered. $A\,F$ is the total secondary induced e. m. f.

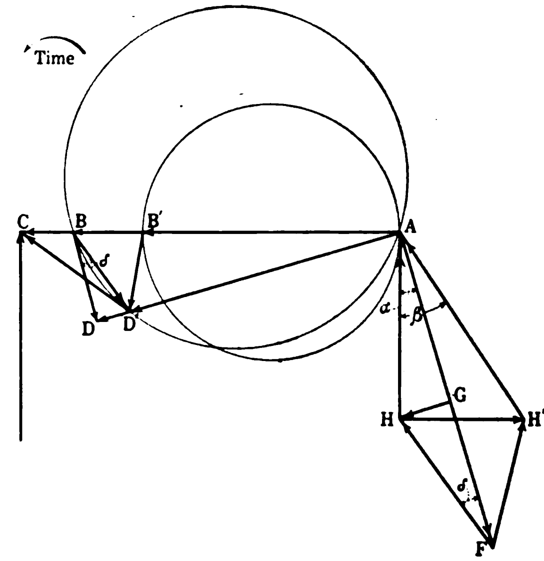

Fig. 14—Circle Diagram of Induction Motor Running Below Synchronism with Regulating Machine Receiving Constant Shunt Excitation, such as to Give No-Load Power Factor Improvement

The secondary current $B^1\,D$ consists of a constant component $B^1\,B$ and variable component $B\,D$. $I\,H^1$ is the constant resistance drop and $H\,I$ the constant leading rotation e. m. f., due to component $B^1\,B$, making H a fixed point. $G\,H$ is resistance drop and $F\,G$ leading rotation e. m. f. of variable component $B\,D$. Now the resistance drop and the variable rotation

e. m. f. are each proportional to the current (the iron of the regulating motor is always at low densities for these near synchronism conditions) hence, angle $H F G = e$ is constant. Since H is a fixed point, angle $H F K = \delta$ can be shown to be constant as in Fig. 13. Angle $K F G = \theta = c + \delta$ = constant. Angle $B D A$ is also equal to θ, since $A D$ is perpendicular to $A F$ and $B D$ is perpendicular to $F G$. So D traces arc of a circle, passing through A and B.

It will be seen then that the power factor and pull-out torque can be improved as well as the speed regulated by this method, when regulating near synchronism, as well as remote therefrom. When we regulate the speed, we so adjust the taps of B, Fig. 12, as to get

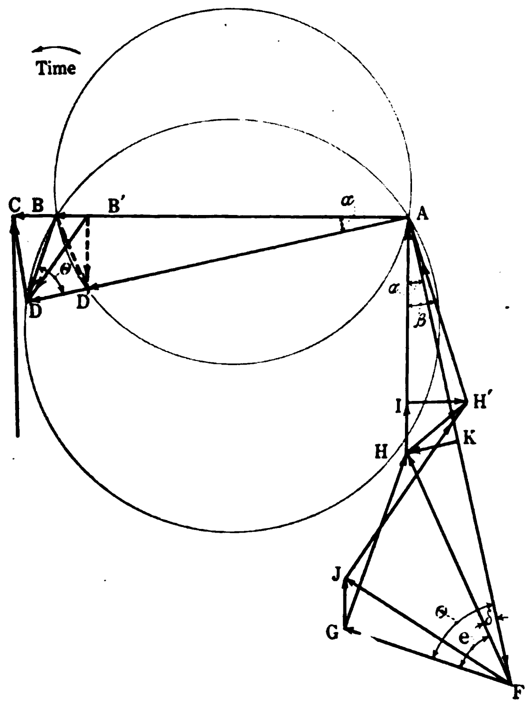

Fig. 15—Circle Diagram of Induction Motor Running Below Synchronism with Regulating Machine Compound-Excited, the Shunt Excitation Being Constant and Having No-Load Power Factor Improvement, and the Series Excitation Yielding E. M. F. 90 Deg. Ahead of the Current

the desired percentage of slip voltage from $F_1 F_2 F_3$ to overcome the reactance drop and then so adjust resistance M that the field current corresponding to the desired conditions will have a resistance drop equal to the voltage supplied by H. As the field current is about constant over the working range of loads we can thus get an even better approximation to Figs. 9 and 11 than without H and M. As we regulate the speed, we thus transfer gradually from the condition of Figs. 9 and 11 to those of Figs. 13, 14 and 15.

We have drawn Fig. 16 to examine the phenomenon of regulating the speed of the main motor while loaded from an infinitesimal amount below synchronism to an infinitesimal amount above synchronism. As the slip is negligible, the total induced e. m. f. is also negligible and the rotational e. m. f. of the regulating set $A H$ just supplies the resistance drop $H A$, the main motor being assumed to be a trifle below synchronism. Let us now assume it to be an infinitesimal amount above synchronism.

All vectors are referred to the secondary whose phase rotation has been reversed, although the physical condi-

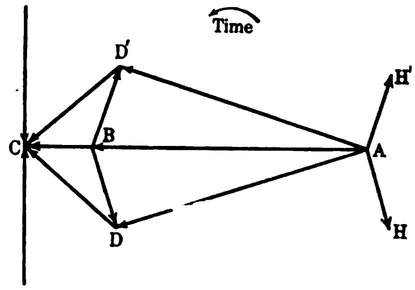

Fig. 16—Diagram of Induction Motor Running Loaded at Synchronous Speed

The same conditions are represented as infinitesimally below and as infinitesimally above synchronism.

tions in the motor remain unchanged. If we select the phase of $A C$ as the phase of reference for both phase rotations, then the components of all vectors in phase with it will not be altered by reversal of the phase rotation, but the quadrature components of all vectors will be reversed, as a vector which would not reach its maximum until 90 deg. after $A C$ will, in reversed phase rotation, reach its 90 deg. ahead of $A C$. This law

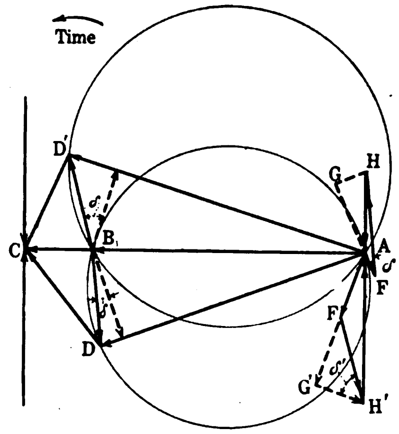

Fig. 17—Circle Diagram of Induction Motor and Constant-Excitation Regulating Machine with One Value of Excitation such that Speed for the Load Point Shown is Nearer Synchronism than the Natural Slip Value and Another Value of Excitation such that Speed for the Load Point Shown is Above Synchronism

yields us $H^1 A D^1 B C$ to represent the same phenomena in terms of reversed phase rotation as are shown by H, A, D, B, C with original phase rotation in the secondary.

In Fig. 17, D is a load point with motor nearer synchronism than its natural slip, as the rotation e. m. f. of the regulating motor $H A$ has been reversed so as to have a large component in phase with the total induced e. m. f., $A F$. The bulk of the resistance drop $F H$ is, therefore, supplied by $H A$, so that $A F$ and consequently the slip are reduced. In these conditions

the motor would pass through and above synchronism as the load dropped off.

Let us now increase $H A$ until the main motor runs above synchronism (with reversed secondary phase rotation). As $H A$ was in quadrature to $A C$, the line

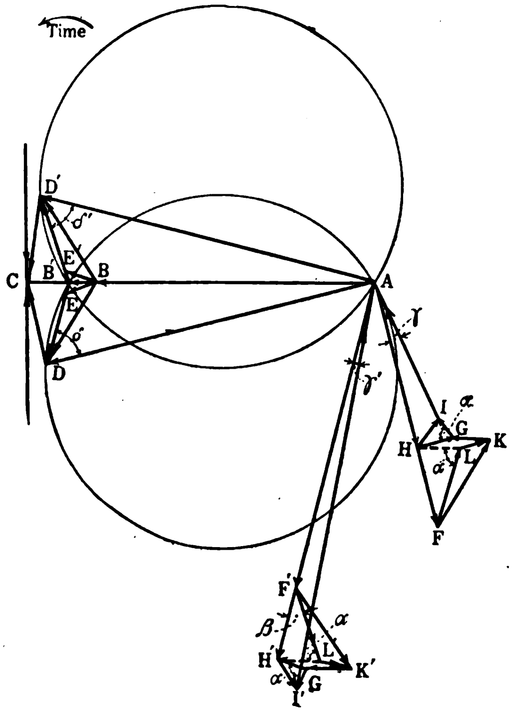

Fig. 18—Circle Diagrams of Induction Motor Running Below Synchronism and Above Synchronism with the Same Characteristics, Controlled in Each Case by a Compound Constant-Speed Regulating Machine

of the phase of reference, its new value will be shown with reversed direction at $H^1 A$. Load point D^1 is above line $A C$ for motor torque for the same reason. The total induced e. m. f. would also be represented with its quadrature component above $A C$ instead of

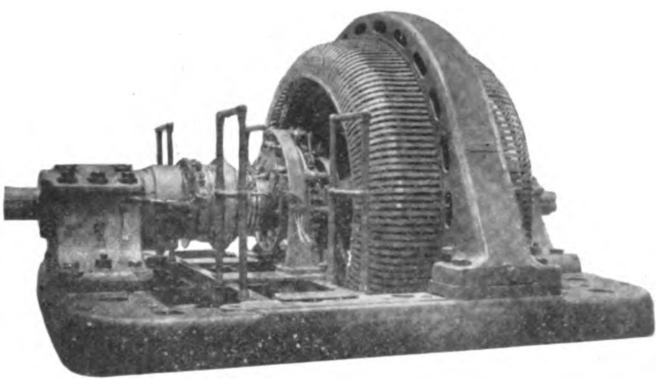

Fig. 19—1200-H.P. Rolling Mill Motor with Frequency-Changer Exciter

below, but its direction is actually reversed, as shown at $A F^1$, since at any instant any given conductor now cuts the flux in the opposite direction.

We note that with no initial quadrature or power factor component in $H A$, and $H^1 A$, the motor characteristic when running above synchronism is better than below in respect to power factor and maximum torque, while for the generator characteristic the converse is true.

Double-Range (Either Above or Below Synchronism) Operation Remote from Synchronism

In Fig. 18, we represent operation both above and below synchronism, with the same speed—torque and speed — power factor conditions. The configuration indicated by the plain letters is for using a compound commutator motor similar to that of Fig. 11, except that angle α has been decreased so that the compounding is mostly in the way of power factor improvement and adds very little to the slip. The primed letters indicate the relations for operating above synchronism and angle $A D^1 B^1$ equals δ can be shown to be constant just as in the case of angle $A D B^1$. Keeping the phase of $A C$ as the phase of reference we note as before that the representation in secondary terms with reversed phase rotation requires the reversal of the components in quadrature with $A C$ of all vectors, and as $A F^1$ is further actually reversed in passing above synchronism,

Fig. 20—A Frequency-Changer Exciter

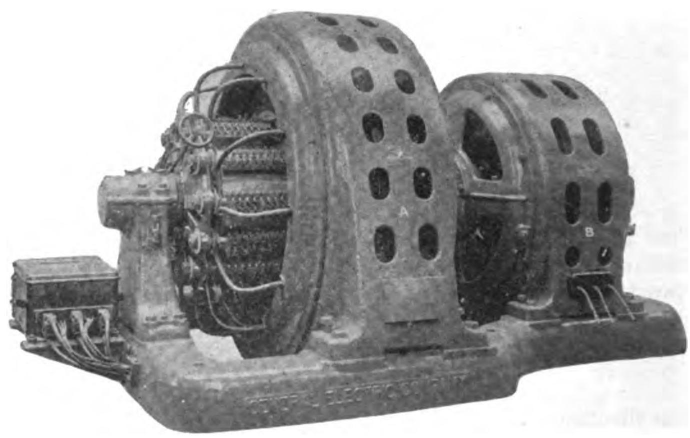

Fig. 21—Speed-Regulating Set for a 1600-H.P. Motor

we see that its quadrature components are still in phase with that of $A F$. But as the regulating machine must furnish power to the main motor secondary in order to satisfy the conservation of energy, the total current $B D^1$ must have a component in phase with the rotation e. m. f. $I^1 A$, which we see is the case, thus requiring that $I^1 A$ be larger than $A F^1$ fulfilling the condition that the regulating machine function as a generator.

Note:—For the development of the circle diagram, particular mention should be made of the works of Behrend, Blondel and Arnold-LaCour. Meyer-Delius has also written concerning what the writer has termed Single-Range Regulation.

The Audion Oscillator

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(*Continued from page* 376 *of JOURNAL for April, 1920*)

18. Operating Point on the Characteristic Curve

By operating point on the characteristic curve is meant the point on the $E_c - I_b$ curve of the audion about which the grid potential and space current vary. E_c is the potential of the grid with respect to the filament. If a continuous negative potential such as Q Fig. 36 is applied, the point about which the variations occur is B. There are several reasons why it is preferable to have B as the operating point rather than A. If A is the operating point, the alternating voltage on the grid makes the grid become positive with respect to the filament during one-half of the cycle, and during that time current flows from the grid to the filament within the audion. This current heats the grid and absorbs power. If the operating point is B, the grid does not become positive with respect to the filament

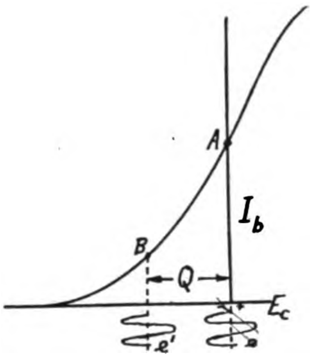

Fig. 36—Operating Points on a Characteristic Curve

at any time and it absorbs no power in varying the grid potential. By using a negative potential on the grid the audion requires no power for varying the grid potential.

If the point A is used as the operating point, the space current flowing is much greater than at B. To maintain the space current at point A requires twice as much filament in an audion as to maintain it at B. At a given temperature (and therefore life of the audion) the space current is dependent upon the amount of filament rather than the voltage used, as the filament is not heated any hotter than is needed to emit the required number of electrons. If we put the same amount of power into an audion at high plate voltage and small plate current (B) as we do with the smaller plate voltage and higher plate current (A), a saving in the required filament and filament power occurs.

19. Methods of Obtaining a Constant Negative Potential

The usual method of securing a constant negative potential for the grid is to use a battery for the purpose Fig. 37. The only objections to such a scheme are the capacity added to the circuit by the battery and the latters likelihood of deteriorating. The scheme shown in Fig. 38 avoids these objections. C_1 is a condenser of low reactance at the operating frequency, and R_1 is a resistance of the order of 10,000 ohms shunting the condenser. Oscillations start with no negative potential on the grid (point A in Fig. 36) and the rectified grid current resulting passes through R_1. In doing so, the rectified current produces a negative voltage which moves the operating point from A toward B. The amount of rectified current produced is reduced, as the

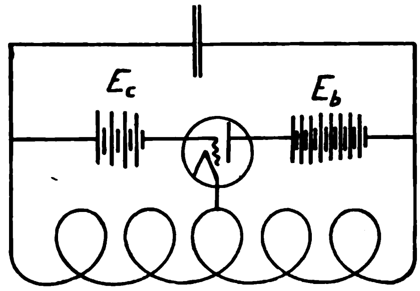

Fig. 37—Hartley Circuit with a Negative Battery for Grid

operating point moves towards the left, due to the smaller time the alternating wave makes the grid positive. The point of equilibrium is reached when this part of the alternating voltage wave is just sufficient to maintain the rectified current through R_1 which produces the continuous negative potential mentioned.

The simplicity of this system is such that it is used in practically all power oscillators. The condenser C_1 is called the grid stopping condenser and the resistance R_1 is called the grid resistance. The latter is sometimes called the grid leak resistance.

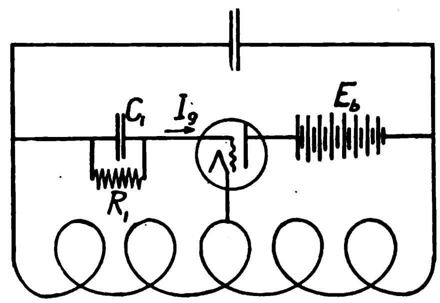

Fig. 38—Hartley Circuit with a Grid Resistance

The behavior of an oscillator with a negative grid battery is different in some ways from that of one with a grid stopping condenser and resistance, as will be indicated later.

20. Dynamic Characteristic of an Audion with Attached Circuit

The static characteristic curve of the audion is as given in Fig. 36. This is the condition of a constant potential on the plate at all grid potentials. When a circuit is attached to the plate of the audion, the potential on the plate no longer remains constant for

all space currents but drops when the current rises. As a result, the curve between the space current and grid potential departs from that given in Fig. 36, and becomes as shown in Fig. 39. It is known as the dynamic characteristic curve of the audion and its circuit. The curve in Fig. 39 is for a pure resistance load circuit $- R$. The load circuit in this diagram is so drawn that the direct current to the audion flows through a large choke coil "*c h*" and produces little or no voltage drop, while all variable currents must pass through the parallel load resistance Z. The effect of the attached circuit is to flatten and straighten the characteristic curve. If the attached impedance is infinite ($Z = \alpha$) the dynamic curve becomes a horizontal straight line.

If an inductive circuit is attached, as in Fig. 40, the dynamic curve becomes a closed loop traveled around in the direction indicated by the arrow. If the circuit has a capacitive reactance as in Fig. 41, the dynamic curve is also a closed loop but it is traveled around in a direction opposite to the one in Fig. 40. These curves must not be confused with hysteresis loops as there is

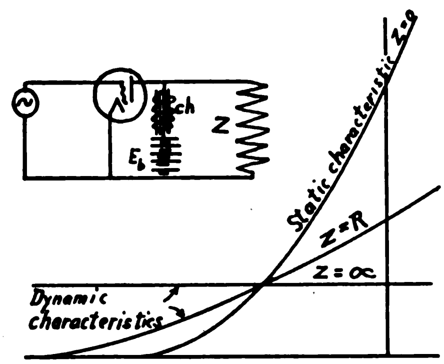

Fig. 39—Static and Dynamic Characteristic Curves with Resistance Load

no connection between them. Hysteresis loops indicate power absorbed. These loops indicate wattless power and are identical in theory with curves plotted between the instantaneous values of an alternating voltage and the resulting current flowing in an inductive or condensive circuit.

21. Coupling for Power

To get the maximum power out of an oscillation generator, the impedance of the attached load circuit must be equal to the internal impedance of the generator, have equal resistance, and have an opposite reactance sign. The internal impedance of an audion is a pure resistance (except at very high frequencies). Ordinary electrical generators are not operated on this principle. If the external impedance equals the internal impedance, a separately excited power generator would have 100 per cent regulation and 50 per cent efficiency. The extra power secured is not worth this sacrifice in efficiency in power work, so that all power machines are constructed to deliver much less than the maximum possible power at a high efficiency.

In audion circuits, a direct current is superimposed on the alternating space current and represents power entirely lost. The maximum possible efficiency is a little over 50 per cent in any case. We must choose, in this class of work, between maximum power (from a given audion) with low efficiency, or a reduced power with a higher efficiency. By operating at a higher voltage, the latter case can give the same power as the former, and we have actually to compare low efficiency (40 per cent) and low voltage, with high efficiency (60

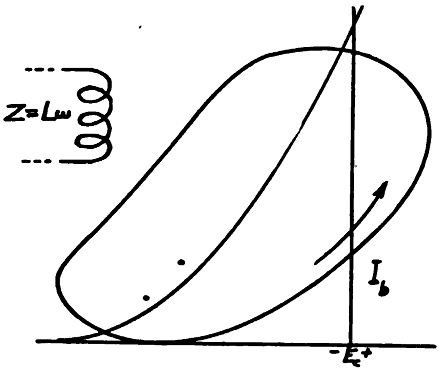

Fig. 40—Dynamic Characteristic with Inductive Load

per cent) and higher voltage. The higher voltage requires more carefully constructed audions, and introduces the attending troubles of higher voltage generators, so that the choice becomes an economic balance between more expensive audions and generators, and the cost of the extra power required in operating the low efficiency circuits. It has been found practicable to choose between these limits in the work to date.

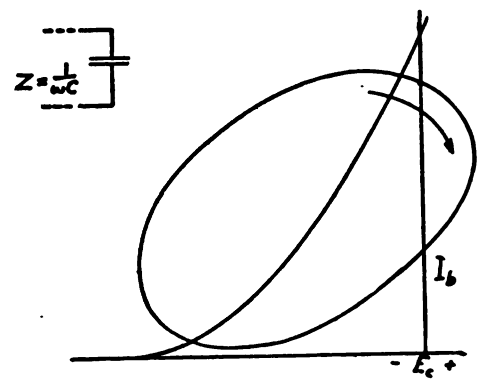

Fig. 41—Dynamic Characteristic with Capacitive Load

22. Audion Output Impedance

The internal impedance (or output impedance) of an audion has been shown by Van der Bijl to be

$$Z_o = \frac{E_b + \mu E_c}{2 I_b} \qquad (3)$$

It is determined by the slope of the $E_b - I_b$ curve at the point of operation. The output impedance Z_o, for the point P, is shown in Fig. 42. For a given audion it is a function of the current, rather than the potentials, for Z_o remains constant as long as the current remains the same, even though E_b and E_c vary. The value of Z_o can be determined from a curve plotted as shown,

although other and quicker ways of measuring it are known.

The output impedance of an audion used in an oscillator is different from the above. The output impedance as defined assumes that the square law characteristic holds, which means that the part of the actual curve over which the operation occurs is limited. The actual characteristic curve of the audion is of the general form shown in Fig. 43, and the operation usually includes the entire region between A and B. For

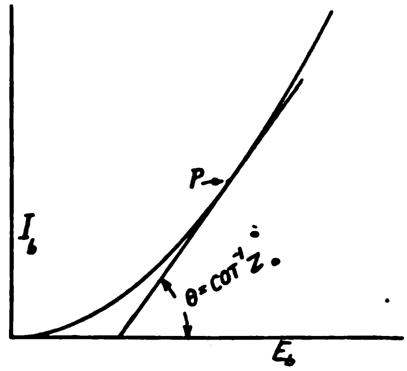

Fig. 42—Relation of Output Impedance and Characteristic Curve Slope

limited amplifier operation, the output impedance is μ times the reciprocal of the slope at P, while for oscillator work it should be more nearly equal to μ times the slope of a line connecting A and B. It actually falls between these two values.

At very high frequencies the output impedance is no longer a pure resistance, due to the plate capacity within. With the internal impedance having a capacitive reactance, it becomes necessary to use a load circuit having an inductive reactance, if maximum power is desired.

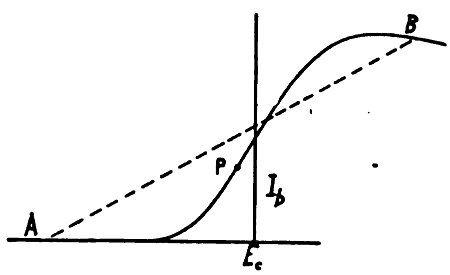

Fig. 43—Influence of Grid and Unsaturated Filament Upon the Form of the Upper Part of the Characteristic Curve

The output impedance of the oscillating audion is most easily determined directly. A curve showing the variation of power secured as a function of the impedance of the load circuit is shown in Fig. 44. The maximum power is secured at the point marked X. This value of impedance is called the output impedance for the oscillating audion.

This curve can be secured by using any of a number of oscillator circuits and varying the coupling between the plate circuit and the oscillation circuit. The one used for this purpose is the one indicated in Fig. 46 where C_p was the adjustable coupling capacity and C_2 was adjusted to compensate for frequency changes produced by varying C_p.

23. Coupling Adjustments

The power delivered by the audion in an oscillator circuit is transferred to the oscillation circuit by means of inductive coupling in the Hartley circuit, and capacitive coupling in the Colpitts circuit. In order to adjust

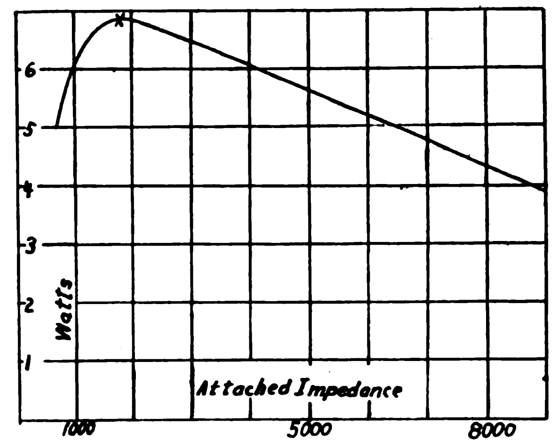

Fig. 44—Influence of Load Circuit upon Output

the impedance introduced into the plate circuit by the oscillation circuit to the proper value, means must be provided for adjusting this coupling. In Fig. 45 the method of making this adjustment for the Hartley oscillator is shown. The inductance L_o is tapped at various points and the connection from the plate is moved along these points until the proper coupling is secured.

There is a limit to which the coupling in this type of circuit can be reduced, due to inherent capacity within

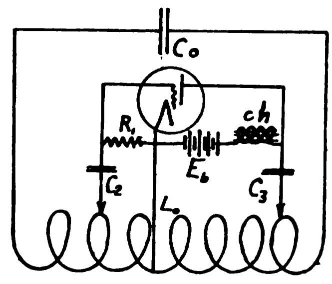

Fig. 45—Adjustments of the Hartley Circuit

the audion. When the amount of L_o included between the plate and grid coupling connections is reduced to a small part of the total inductance, a second oscillator circuit is formed having this inductance as the oscillation circuit inductance and the grid to plate capacity as the oscillation circuit capacity. At the high frequency of this parasitic oscillation circuit the remaining part of L_o and C_o has a large inductive reactance and does not affect its oscillations. The circuit when constructed in this maner is likely to operate entirely at

the high parasitic frequency and not at the frequency for which the circuit was originally designed. The Colpitts circuit avoids this particular kind of trouble.

Fig. 46 shows a Colpitts circuit with a method of adjustment. The plate coupling is adjusted by varying C_p. However as this adjustment changes the frequency, a second adjustable condenser C_a is needed to bring the frequency back to the desired value. This circuit has the disadvantage that two adjustments are

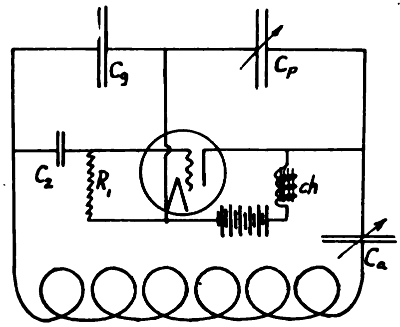

Fig. 46—One Manner of Adjusting the Colpitts Circuit

necessary for one adjustment of coupling, a condition which is not required in the Hartley circuit.

To avoid this double adjustment, and also to avoid the Hartley circuit troubles, a modified method of adjustment can be made as shown in Fig. 47. Instead of varying the condenser C_p, the mutual capacitive reactance is varied by introducing, in series, a varied amount of inductive reactance. This is secured by moving the coupling tap along the inductance coil L_o. The reactance of the inductance connected between C_p and the coupling point Q is opposite in sign to the reactance of C_p itself and thereby changes the mutual reactance. The adjustment of coupling in this manner

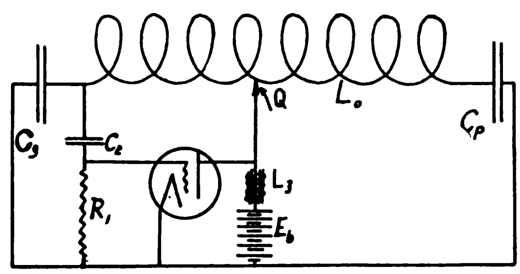

Fig. 47—Complete Colpitts Circuit with Coupling Adjustment

does not affect the wave-length appreciably nor produce a parasite frequency circuit, as in the Hartley circuit.

24. Audion Load Circuit

The circuit connected between the plate and filament of an audion is called the load circuit. In the Hartley circuit it has the actual form shown in Fig. 48, and is electrically equivalent to that shown in Fig. 49. The mutual inductance, in the first case, is the mutual between L_1 and all of L_2, and is to be the same as M in the second case. If an alternating voltage E is impressed across L_1 (or L_3), power is transferred to the oscillation circuit $L_2\,C_2$ (or $L_4\,C_4$) by this mutual inductance. The current through L_1 (or L_3) will have the value

$$I = \frac{E}{\sqrt{(R_1 + R_i)^2 + (X_1 + X_i)^2}} \tag{4}$$

where R_1 and R_i are respectively the primary resistance and the resistance introduced, and X_1 and X_i are respectively the primary reactance and the reactance introduced from the secondary. The values of resist-

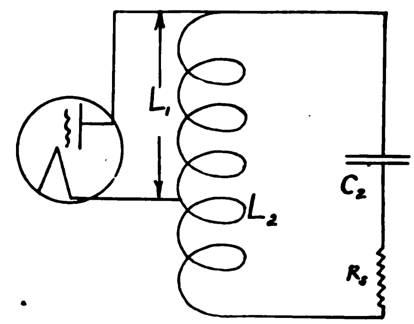

Fig. 48—Hartley Circuit Coupling

ance and reactance introduced due to the mutual reactance are

$$R_i = \frac{M^2\,\omega^2\,R_s}{R_s^2 + \left(L_s\,\omega - \dfrac{1}{\omega\,C_s}\right)^2} \tag{5}$$

$$X_i = -\frac{M^2\,\omega^2\left(L_s\,\omega - \dfrac{1}{\omega\,C_s}\right)}{R_s^2 + \left(L_s\,\omega - \dfrac{1}{\omega\,C_s}\right)^2} \tag{6}$$

where R_s, L_s and C_s are the secondary resistance, inductance, and capacity. The form of these curves are given in Fig. 50.

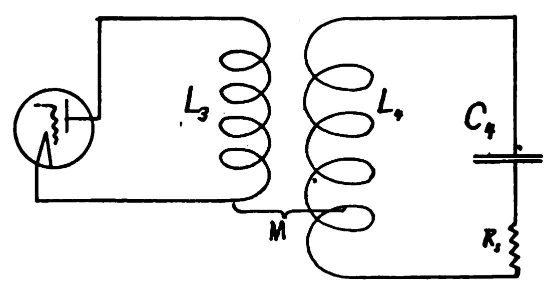

Fig. 49—Equivalent of Coupling of Hartley Circuit

Inspection of these equations will show that at the resonant frequency of the secondary

$$R_i = \frac{M^2\,\omega^2}{R_s} \tag{7}$$

$$X_i = 0$$

or resistance only is introduced into the primary. The minus sign in front of the reactance term indicates that at other frequencies when the reactance in the secondary circuit is inductive, the reactance introduced into the primary is capacitive, and vice versa. Above resonance, the secondary circuit has inductive reactance and may introduce enough capacitive reactance into

the primary to more than neutralize the primary inductive reactance. The reason circuits of this kind sometimes tune at a higher frequency than the resonant frequency of the secondary is because under these conditions enough capacitive reactance is introduced

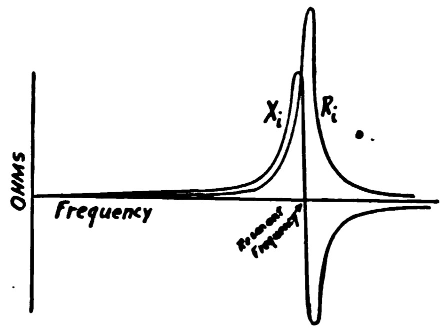

FIG. 50—RESISTANCE AND REACTANCE INTRODUCED INTO THE PRIMARY FROM THE SECONDARY CIRCUIT

into the primary to resonate with the primary inductance and improve the power factor of the entire primary circuit. Under these conditions the applied e. m. f. will deliver more power to the circuit which makes itself evident by a larger secondary current.

For a capacitive coupling between the audion and the oscillation circuit, as in Fig. 51, the resistance and reactance values are

$$R = \frac{(R_1 R_2 - X_1 X_2)(R_1+R_2) + (R_1 X_2 + R_2 X_1)(X_1+X_2)}{(R_1+R_2)^2 + (X_1+X_2)^2} \tag{8}$$

$$X = \frac{(R_1+R_2)(R_1 X_2 + R_2 X_1) - (X_1+X_2)(R_1 R_2 - X_1 X_2)}{(R_1+R_2)^2 + (X_1+X_2)^2} \tag{9}$$

where $X_1 = -\frac{1}{\omega C_1}$ and $X_2 = \left(L_2\,\omega - \frac{1}{\omega C_2}\right)$

If $R_1 = 0$, a condition approximated in practise,

$$R = \frac{\left(-\frac{1}{\omega C_1}\right)^2 R_2}{R_2^2 + \left(L_2\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2}\right)^2} \tag{10}$$

$$X = -\frac{1}{\omega C_1} - \frac{\left(-\frac{1}{\omega C_1}\right)^2 \left(L_2\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2}\right)}{R_2^2 + \left(L_2\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2}\right)^2} \tag{11}$$

which have the identical form of the equations with inductive coupling, but with a reactance $-\frac{1}{\omega C}$ replacing $M\,\omega$. The equations give curves of the form shown in Fig. 51.

In the actual Colpitts circuit, the coupling adjustment shown in Fig. 47 gives a more complicated expres-

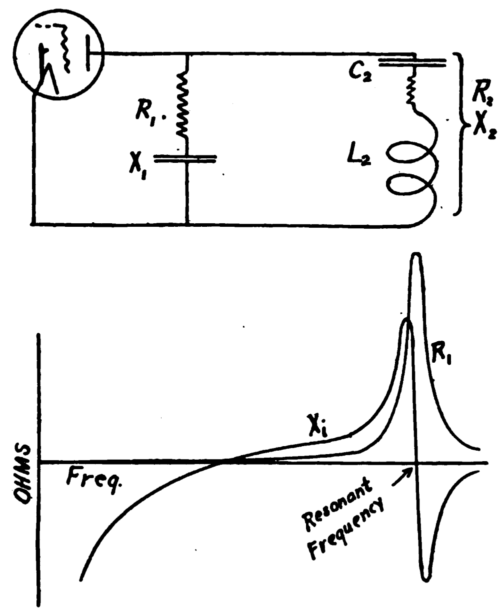

FIG. 51—CAPACITIVELY COUPLED CIRCUIT WITH ITS RESISTANCE AND REACTANCE CURVES

sion. The load circuit is also shown in Fig. 52 where the parts of the inductance acting as mutual reactance are called L_1 and the remainder L_2. The values of resistance and reactance connected to the audion plate circuit with this arrangement are given by

$$R = \left[\frac{\left(R_1 R_2 - \left(L_1\,\omega - \frac{1}{\omega C_1}\right)\left(L_2\,\omega - \frac{1}{\omega C_2}\right) + M^2\,\omega^2\right)(R_1+R_2) + \left[R_2\left(L_1\,\omega - \frac{1}{\omega C_1}\right) + R_1\left(L_2\,\omega - \frac{1}{\omega C_2}\right)\right]\left[L_1\,\omega + L_2\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2} + 2\,M\,\omega\right]}{(R_1+R_2)^2 + \left(L_1\,\omega + L_2\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2} + 2M\,\omega\right)^2}\right] \tag{12}$$

$$X = \frac{\left[R_2\left(L_1\,\omega - \frac{1}{\omega C_1}\right) + R_1\left(L_2\,\omega - \frac{1}{\omega C_2}\right)\right](R_1+R_2) + \left[L_o\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2}\right]\left[R_1 R_2 - \left(L_1\,\omega - \frac{1}{\omega C_1}\right)\left(L_2\,\omega - \frac{1}{\omega C_2}\right) + M^2\,\omega^2\right]}{(R_1+R_2)^2 + \left(L_o\,\omega - \frac{1}{\omega C_1} - \frac{1}{\omega C_2}\right)^2} \tag{13}$$

which produce curves of the form in Fig. 52.

At the resonant frequency of the oscillation circuit they reduce to

$$R = \frac{R_1 R_2 + M^2 \omega^2 - \left(L_2 \omega - \frac{1}{\omega C_2}\right)\left(L_1 \omega - \frac{1}{\omega C_1}\right)}{R_1 + R_2} \tag{14}$$

$$X = -\frac{R_1\left(L_2 \omega - \frac{1}{\omega C_2}\right) + R_2\left(L_1 \omega - \frac{1}{\omega C_1}\right)}{R_1 + R_2} \tag{15}$$

25. Oscillator Behavior as a Function of Its Variables

An oscillator constructed in the manner outlined, has, when designed for a certain frequency, six independent variables which influence its operation. These

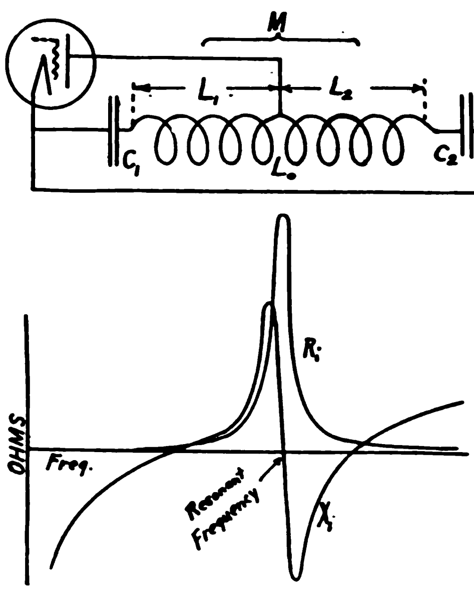

Fig. 52—Coupling Circuit of the Colpitts Oscillator with its Resistance and Reactance Curves

are, plate voltage, filament voltage or current, plate coupling, grid coupling, oscillation circuit resistance, and grid resistance. The three dependent variables which indicate its behavior are, space current, grid current, and oscillation current. These independent variables do not include variations in audion constants for different audions, but are concerned only with the behavior of the circuit having a particular audion. They also do not include variations in elements of the circuit which ordinarily should have zero or infinite impedances such as the grid stopping condenser C_2 and the choke coil L_3 Fig. 47.

The plotting of a curve, surface, solid, etc. to represent the oscillator behavior as a function of the six variables is beyond the realm of possible geometry and it devolves into the plotting of six sets of curves under arbitrarily chosen conditions. To show completely the circuit behavior, a large number of combinations should be chosen. However, it has been found that certain elements have greater influence than others and the number required can be reduced. It has been found sufficient to plot families of curves using R_1 as one independent variable and each of the other five variables in turn, as another, and secure a very informative set of curves. The circuit used to give the following curves was adjusted to a best operating condition,

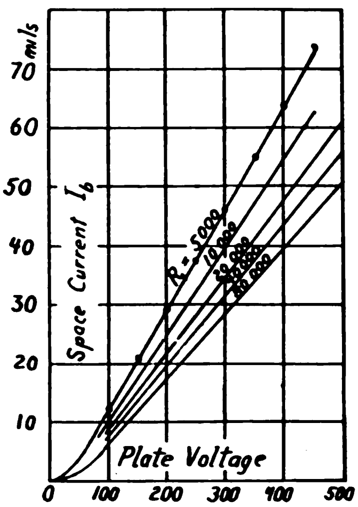

Fig. 53—Oscillator Space Current as a Function of Plate Voltage

as will be pointed out later, and then each independent variable successively varied, but always returned to its original value while another variable was being changed. The curves therefore show the behavior of the oscillator around the point of best operation, as a function of each of the six independent variables in turn, or as a function of R_1 and one of the other five variables in turn.

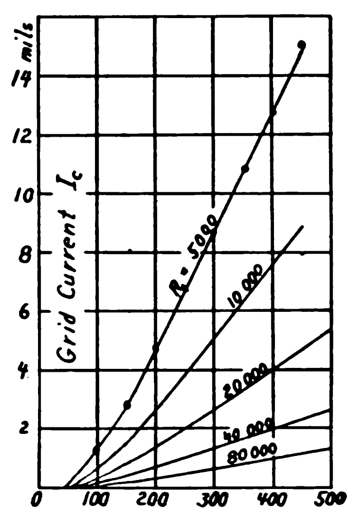

Fig. 54—Oscillator Grid Current as a Function of Plate Voltage

26. Variation as a Function of E_b

The space, grid, and antenna currents I_b, I_c, and I_a all vary as straight line functions of E_b except at the very ends of the curves, where either oscillations do not occur or filament temperature saturation does not occur. Curves are shown in Figs. 53, 54 and 55 for an

E type Western Electric audion with various values of R_1. All the curves converge toward a value of E_b equal to about 50 volts, which means that no oscillations occur until about that value is reached.

The use of a grid resistance instead of a negative grid battery makes quite a difference in the shape of these curves. In Fig. 56 curves are shown of I_b and I_d as a function of E_b, for the latter case. The oscillations do not start as low and make a big jump when they do start. Further, there is a place where a different path is followed with a decreasing plate voltage rather than with an increasing voltage. The simple behavior of the circuit with the grid resistance is an additional reason for using it in place of a constant negative potential on the grid.

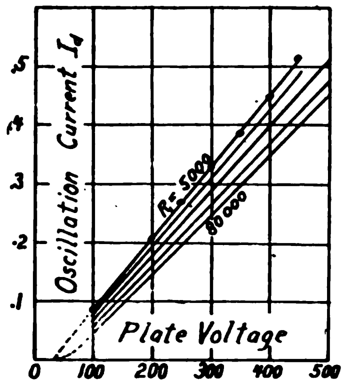

Fig. 55—Oscillation Current as a Function of Plate Voltage

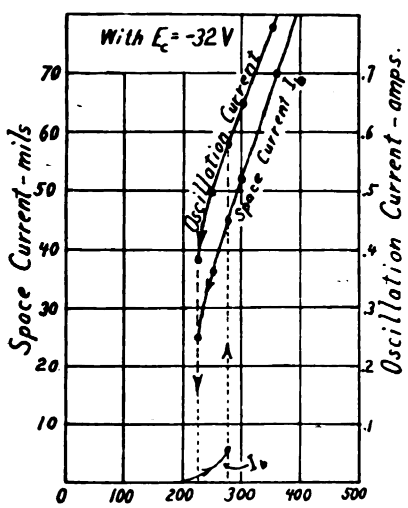

Fig. 56

27. Variation with Filament Current

The control of the filament current of an oscillator is as important as the regulation of any power generator. The filament current bears about the same relation to an audion that the field current does to a generator. It acts as an exciter, and produces the free electrons by thermal emission. It is, however, a much more sensitive exciter than the generator field current since the emission of electrons only begins at about two-thirds the operating value of the current and is not proportional to it but varies rapidly with it. A curve showing the oscillator behavior as a function of filament current is shown in Fig. 57. The variation of power output with filament current is very large at some points, but above about 1.35 amperes it changes very slowly. It is highly desirable to make the oscillator's operation independent of as many variables as possible and, by keeping the filament current above 1.36 amperes, the fluctuations in filament current have little or no effect. At the same time is it not desirable to run the filament current higher than is necessary, as the life of the audion is shortened thereby.

The filament current at which oscillations begin in the type E audion varies from 1.0 to 1.25 amperes depending upon the emissivity of the filament. A filament with very good emission begins at the lower value, and the curve flattens off at the value of 1.15 amperes. A passable filament begins at 1.25 and reaches the flat portion of the curve at 1.4 amperes. The average filament is such that oscillations begin at

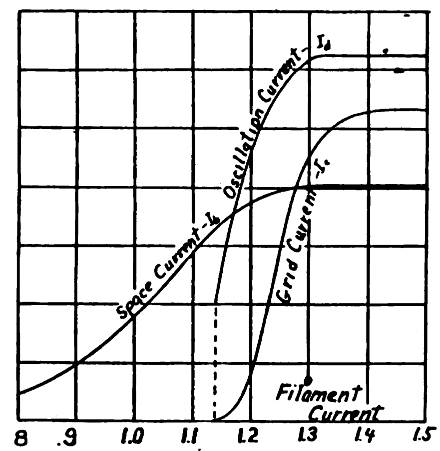

Fig. 57—Oscillator Behavior as a Function of Filament Current

1.15 and flatten off at 1.3 amperes, as shown in Fig. 57. With the average audion, operating at 1.35 amperes, the filament current can vary a considerable amount on either side and not affect the power delivered.

These curves are for a plate voltage of 300. If the voltage is raised, the saturation point is shifted to a higher value. The amount of this shift is not very great however, and as this type of audion is not built to work safely at much over 300 volts, the values given are satisfactory up to 400 volts.

Figs. 58, 59 and 60 show a family of these curves with various values of R_1. The larger values of R_1 cause the curves to flatten out at a lower filament current value thereby allowing satisfactory operation at a lower filament current. The power output, however, is reduced. A compromise must be made, in a given case, between the high current with more power but short life, and lower current with less power and longer life.

The value at which the oscillations start in the average case is 1.15 amperes. It is possible to adjust an

oscillator circuit so that oscillations will begin as far down as 0.95 amperes, but such an adjustment will give neither the maximum power conditions in the proper operating regions nor anywhere near the proper grid current for satisfactory behavior. These curves indicate only the operation around the region of adjustment for greatest power.

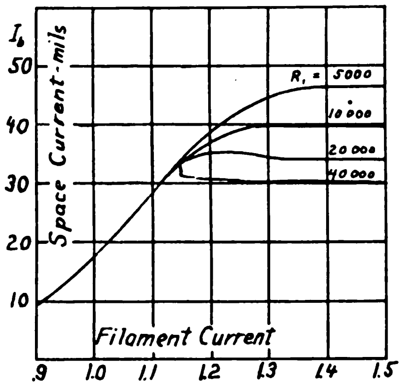

FIG. 58—OSCILLATOR SPACE CURRENT AS A FUNCTION OF FILAMENT CURRENT

Since increasing R_1 makes the flat portion of the oscillation current curve begin at a low value this can be used to counteract the reverse shift caused by raising the plate voltage. The two shifts are such that, by raising both R_1 and the plate voltage the flat part of the curve remains the same, but the power is increased. For greater power, if low filament current and long life is desired, this combination accomplishes the purpose.

28. VARIATION WITH COUPLING

The behavior of the oscillator as influenced by the impedance of the load circuit is shown in Fig. 61. The oscillation current is seen to reach a maximum when the attached impedance is 1800 ohms. The maximum point is not sharply defined. The impedance may be varied between 1000 to 5000 ohms with very little change in power output. The space current, however,

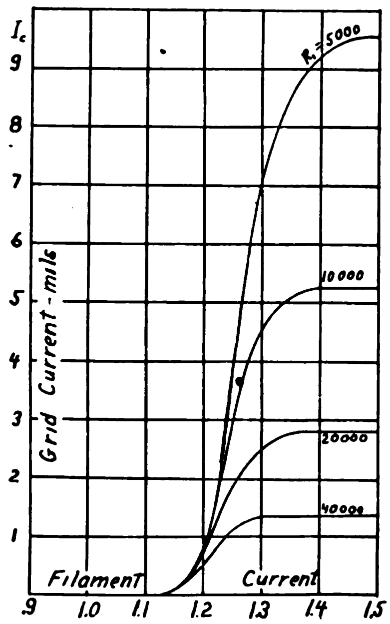

FIG. 59—OSCILLATOR GRID CURRENT AS A FUNCTION OF FILAMENT CURRENT

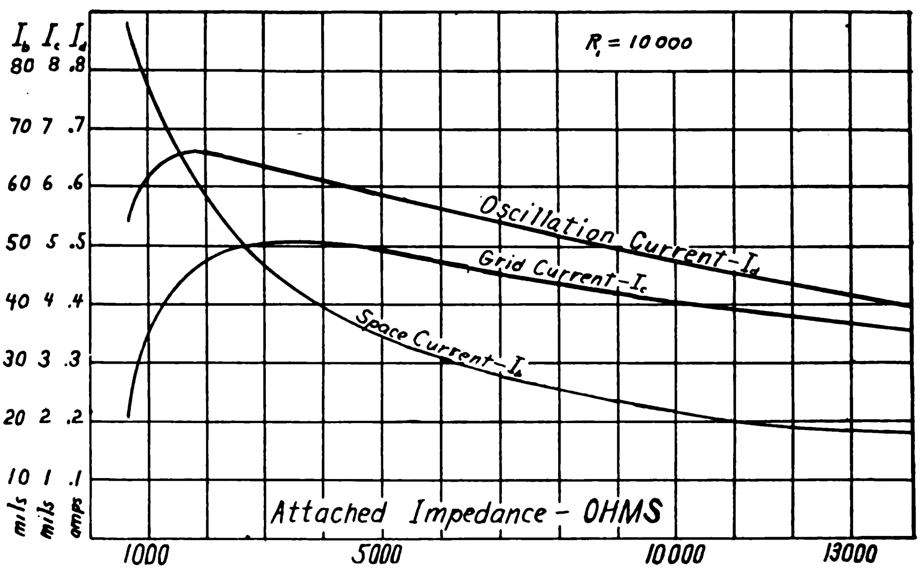

FIG. 61—BEHAVIOR OF AN OSCILLATOR AS A FUNCTION OF PLATE COUPLING. R_1 = 10,000

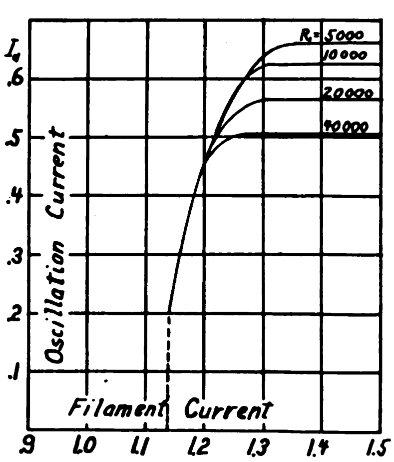

FIG. 60—OSCILLATION CURRENT AS A FUNCTION OF FILAMENT CURRENT

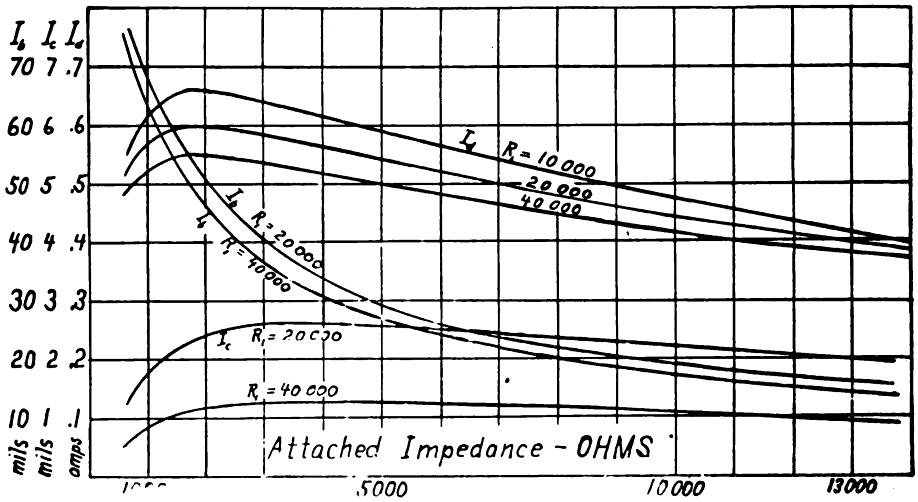

FIG. 62—BEHAVIOR OF AN OSCILLATOR AS A FUNCTION OF PLATE COUPLING AT VARIOUS VALUES OF R_1

decreases rapidly as the impedance increases, and the efficiency increases accordingly. The operation of the audion with an impedance of 3000 to 6000 ohms gives so much better efficiency than is obtained at the point of maximum power that it usually pays to sacrifice the power output to get the efficiency. If the power is needed badly however, raising the plate voltage will bring up the power and yet keep up the efficiency. The practise adopted is therefore to couple closer than

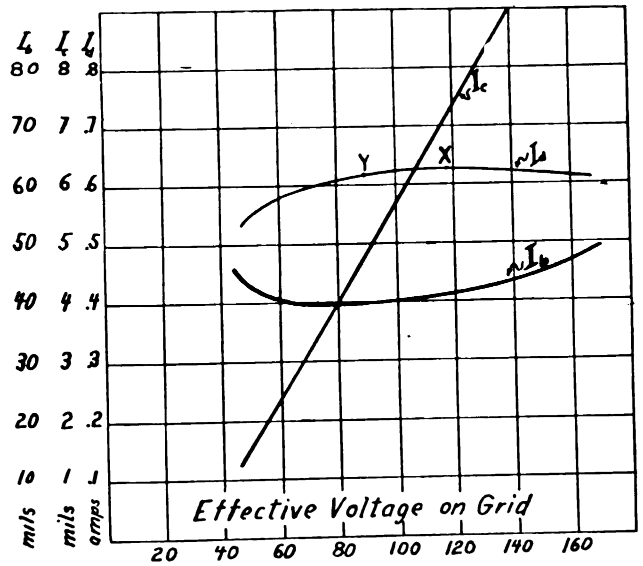

Fig. 63—Effect of Input Voltage on Grid upon Output

is needed to give the maximum of power in order to secure better efficiency.

Curves for other values of R_1 are shown in Fig. 62. They show chiefly a reduction in power, in and out.

29. Variation with Input on Grid

In the writer's mathematical treatment of the oscillator (in course of publication) a curve is plotted showing the boundary conditions between the oscillatory and non-oscillatory states of a circuit where the resistance necessary to stop the oscillations is plotted as a function of the ratio of plate coupling to the sum of plate and grid couplings. There is also made the statement that with the grid coupling (L_g) slightly larger than the plate coupling (L_p) the circuit would continue to oscillate with the greatest amount of resistance, but, that that was not necessarily the condition of maximum power. This agrees entirely with the case of any electrical generator where, if the adjustments are made to take care of the most adverse conditions, under proper normal conditions such an adjustment will not be the best. A principal factor in causing this difference is the absorption of power by the grid. If the grid absorbed no power, and we increased the input alternating voltage upon it, the power delivered would increase, if the current were not striking the top and bottom of the characteristic curve (B and A in Fig. 43), and would remain constant if it were, which latter is the usual case. However, since the raising of the input voltage does produce more rectified current to the grid, there is an increase in the power absorbed and no increase in that delivered. The result is that raising the grid input beyond a certain amount begins to cause a reduction in power in the oscillation circuit. From this consideration alone, we should make the coupling to the grid large enough to secure maximum power and no larger.

A second reason for making a proper adjustment of input to the grid is to prevent its being overheated. The flow of rectified current from the grid to the filament heats the grid sufficiently to weaken it or cause it to emit electrons itself. In the latter case current flows both ways between the grid and filament, absorbs power, overheats the filament, and reduces the rectified current to the grid. A further trouble thus caused is an overheating of the audion without an increase in power. On account of the likelihood of overheating of the grid, no larger grid input should be used than is necessary for maximum power. Fig. 63 gives curves of space, grid, and antenna currents as a function of grid input. The output of maximum power is indicated at X for a grid voltage of 120 volts. However, the point Y is better than X as the output power is almost the same though the plate power is less. The greater efficiency is worth the sacrifice in power, especially as the latter may be compensated for by raising the plate voltage. At the same time, point Y produces a much smaller grid current and the likelihood of overheating of the grid is less.

30. Variation with Antenna Resistance

In a previous section on coupled circuits it was shown that increasing the resistance of the secondary at

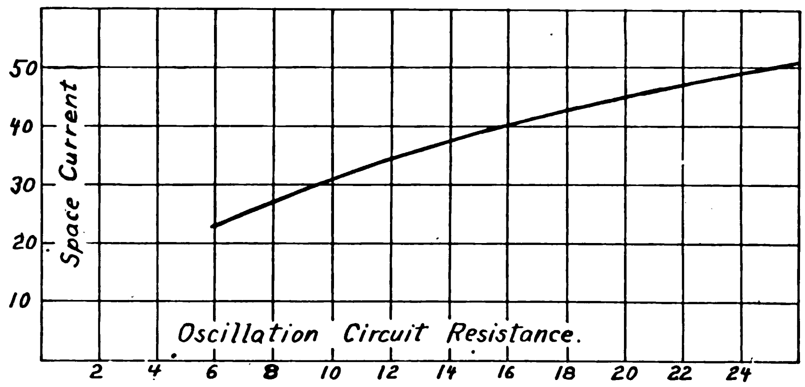

Fig. 64—Effect of Varying Oscillation Circuit Resistance

resonance, reduced the resistance introduced into the primary. In oscillators, reducing the resistance in the oscillation circuit makes the dynamic characteristic curve of the audion and circuit vary in shape, or size, or both. This variation causes an increase in the so called "rectified" current through the audion. In Fig. 64

is shown a curve between antenna resistance and space current. It is not far from a straight line. With high amplification constant audions and certain circuit adjustments (large grid input) a curve is secured which is straight over a considerable portion of its length.

The relation existing between oscillation circuit resistance and space current gives us a very convenient method of measuring antennae capacities and resist-

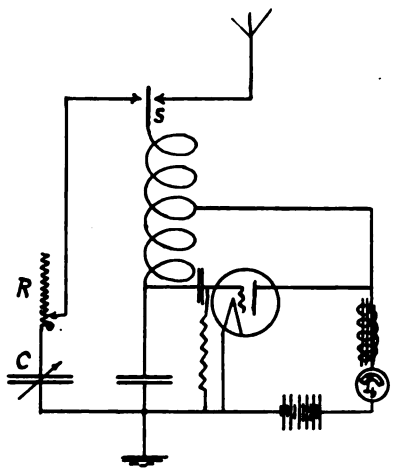

FIG. 65—MEASURING CIRCUIT FOR ANTENNA CONSTANTS

ances. An oscillator is connected to an antenna and adjusted properly at the wave-length at which it is desired to know the effective capacity and resistance. The space current is then noted. The switch S Fig. 65 is then thrown, putting the oscillator onto a dummy antenna whose capacity C is adjusted to give the same wave-length and resistance R to give the same space current. The values of C and R are then the effective

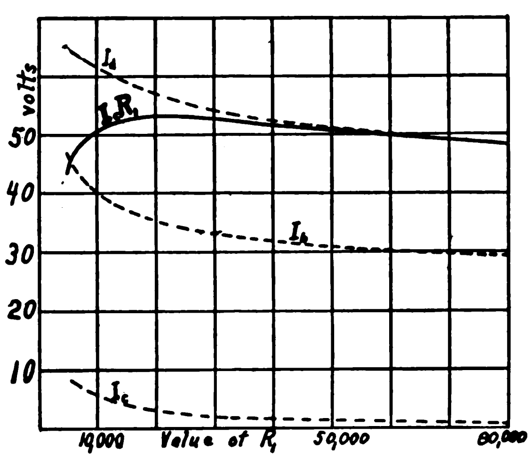

FIG. 66—CONTINUOUS POTENTIAL ON GRID PRODUCED BY I_c THROUGH R_1

capacity and resistance of the antenna at the wave-length in question.

31. VARIATION WITH GRID RESISTANCE

Curves were shown in Fig. 53, and others, showing how varying the grid resistance changed the form of the curves. Fig. 66 shows how the grid resistance affects the space, grid, and antenna currents, all other things being kept constant. In all cases, increasing R_1 reduces them. Fig. 66 also shows the negative potential produced by the grid current $I_c R_1$ as a function of R_1. The potential is nearly constant throughout. It may, however, take an entirely different form as the latter is dependent upon the adjustment of the circuit and the constants of the audion. The curve given is that for the type E audion with the adjustment giving maximum power.

32. EFFICIENCY

By efficiency of an oscillator is meant plate efficiency only—oscillation current power divided by plate power supplied.

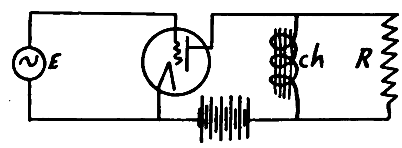

FIG. 67—AUDION WITH LOAD CIRCUIT R AND VARIABLE VOLTAGE INPUT E

The theoretical efficiency of an audion circuit is difficult to determine. It depends too much upon the assumptions as to how it operates. If the circuit is assumed as of the form in Fig. 67, we have the d-c. loss only within the audion, and an a-c. dissipation of power both in the audion and in R. All the direct current passes through the large choke coil and the alternating current through the resistance R. If we assume the space current has the form shown in Fig. 68 consisting of a constant value A and a variable sine wave

$$i = A\,(1 + \sin \omega t) \qquad \textbf{(16)}$$

and assume also that the impedance of the audion is constant, the power out is given by $R\ A^2/2$, and the

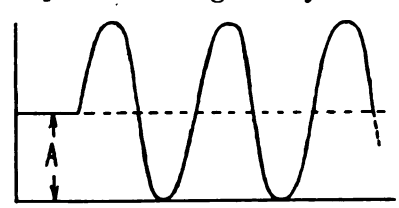

FIG. 68—ASSUMED SPACE CURRENT $i = A\ (1 + \sin \omega t)$

power dissipated, both d-c. and a-c. is given by $A^2 Z_o + Z_o A^2/2$. The efficiency is then

$$e\,f\,f = \frac{\frac{A^2 R}{2}}{Z_o\,(A^2 + A^2/2) + R\,A^2/2} = \frac{R}{3\,Z_o + R} \qquad \textbf{(17)}$$

Theoretically on this assumption we can approach 100 per cent efficiency if R is made large enough, and if $R = Z_o$ the efficiency is 25 per cent. Actually neither is found correct.

If we assume that the resistance of the audion varies between zero and infinity in such a manner as to produce the current mentioned in (**16**) through the audion, the power dissipated in R is $R\ A^2/2$ as all the alternat-

ing current must go through R, and the power supplied is $E\,A\,(1 + \sin w\,t)$ where E is the voltage of the B battery. This integrates over a cycle into $E\,A$. When the audion's resistance is zero the total plate voltage is across R, which gives us the value of E in terms of A and R ($E = A\,R$). The efficiency is then

$$eff = \frac{\frac{A^2 R}{2}}{E\,A} + \frac{\frac{A^2 R}{2}}{A^2 R} = 50 \text{ per cent} \qquad (18)$$

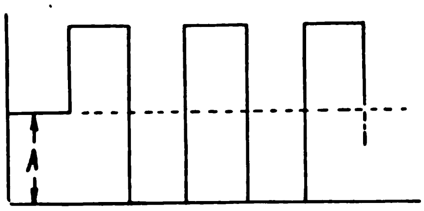

FIG. 69—RECTANGULAR FORM OF ASSUMED SPACE CURRENT

This value is likewise in error as regards the efficiency at maximum power conditions. The audion's resistance does not decrease to zero and the actual efficiency is therefore lower. Experience has shown it to be in the neighborhood of 35 per cent but even then it varies with the type and constants of the audions. It is even possible to secure greater efficiencies than 50 per cent. Using the audion as an amplifier only and taking out power into a tuned circuit has given efficiencies as high as 80 per cent. Using it in oscillators has given efficiencies as high as 70 per cent and there is no reason to suppose that it should be lower than the amplifier value. If the resistance of the audion could be varied between the limits of zero and infinity instantly in a periodic manner a current of the form shown in Fig. 69 would be produced through the audion. With a variable resistance of this kind 100 per cent efficiency would be secured as no power would be lost in the audion. The previous figure of 50 per cent efficiency was based on a zero to infinity variation in resistance, but it varied in such a manner that the resistance was finite for a part of the time producing a sine current, and power was thereby absorbed. In an audion the resistance does not vary between zero and infinity but varies between a finite value and infinity, this tends to make the efficiency lower than 50 per cent. However, it also does not vary in such a manner as to produce a sine current but passes through the intermediate values at a much faster rate than would produce a sine current. This manner of variation approaches the hypothetical variable resistance producing the current in Fig. 69 and tends to make the efficiency approach 100 per cent. The result of the finite limit in resistance in one direction, and the rapid variation through the intermediate values, causes the oscillator to have efficiencies of the order mentioned.

Fig. 70 shows an efficiency curve for an oscillator as a function of plate voltage. The curve shows that efficiencies of over 50 per cent can be secured and that it is still rising, though slowly with plate voltage.

In Fig. 71 is shown a curve of efficiency as a function of attached plate impedance. It shows, as would be expected, that the larger the external impedance, the greater the efficiency. Such a condition is indicated also in Fig. 64 by the rapid drop in space current. The power secured is reduced at the higher values of attached impedance as is the case with any electrical machine under similar conditions. The curve shows a tendency to drop after reaching the value of 9000 ohms but this is due to the reduced power delivered producing a reduced voltage on the grid. A readjustment of the circuit to put the grid input voltage as high at this point as at 2000 ohms, causes the curve to rise and to continue rising until a similar condition occurs again.

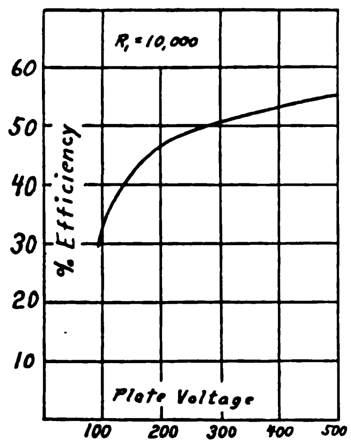

FIG. 70—EFFICIENCY OF AN OSCILLATOR AS A FUNCTION OF PLATE VOLTAGE

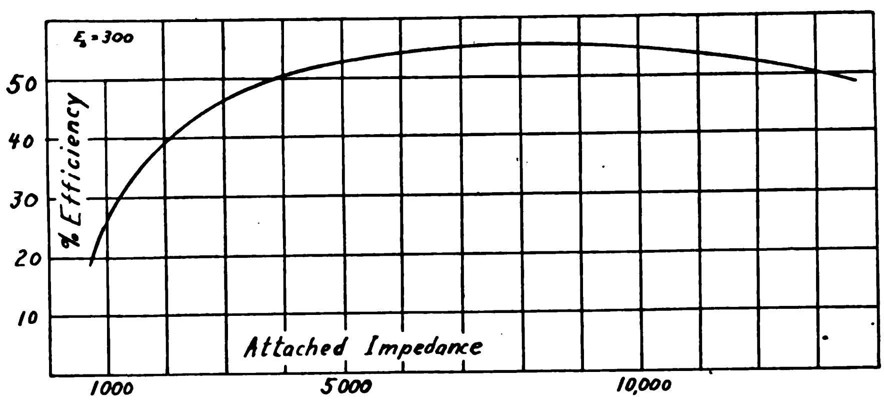

FIG. 71—EFFICIENCY OF AN OSCILLATOR AS A FUNCTION OF PLATE CIRCUIT IMPEDANCE

33. OSCILLATOR ADJUSTMENTS

The adjusting of an oscillator for maximum power is ordinarily a cut and try process. This is especially so if all the independent variables are varied. It is possible, however, to reduce the work to a negligible amount by the adoption of a system based on the curves given. This is accomplished by a systematic assumption of values for a few of the variables, and the

reduction of the final adjustment to the variation of grid and plate coupling. First, then, the filament current should be set. It should be set at the saturation value represented by 1.35 amperes for the *E* type audion in Fig. 57. The grid resistance should next be set at the desired value. This value may be determined from Fig. 72 which gives the power obtainable from this type of audion for various values of grid resistance and plate voltage. The plate voltage should also be determined on. This then reduces the remaining adjustments to two, plate coupling, and grid coupling. The oscillator circuit should be set for the desired wave length and the plate voltage at some value, preferably the value at which the circuit is to operate. From curves in Figs. 53 and 54 find the space and grid currents which should flow at the chosen plate voltage and with the chosen grid resistance. Complete the two remaining adjustments by varying the two couplings—plate and grid, until the space and grid currents so found are secured. The oscillator circuit will then be found to be adjusted for almost maximum power, and good efficiency, as pointed out in the last few paragraphs.

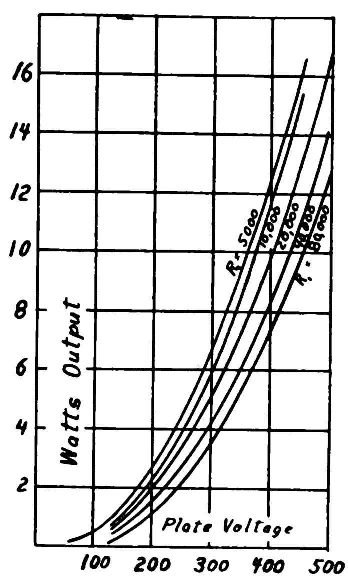

Fig. 72—Power Output of Type *E* Audion

The curves given in these paragraphs apply to the Western Electric Co. *E* type audion. For other types, a complete set must be secured experimentally. Once a set is secured and plotted, the work spent in adjusting circuits is greatly expedited.

34. The Three Adjustments

In any oscillator, either for wireless sets or other purposes, it often becomes necessary to vary the frequency. Such a change in the circuit usually throws out the adjustment. When a set is once constructed the number of adjustments required for such a change is reduced to three. The grid resistance, plate voltage and filament current are already fixed by the construction of the set. The remaining adjustments are frequency, plate coupling and grid coupling. To change the frequency or wave length,

1. Change the oscillation circuit to give the new frequency,
2. Adjust coupling until the grid current is the required value,
3. Adjust coupling until the plate current is the required value.

The second and third adjustments may affect the first a trifle and vice versa so that they should be gone over a second time.

The simple relation connecting grid and space currents with grid and plate couplings, and plate voltage makes the adjustment of an oscillator a much simpler matter than the adjustment of most radio apparatus. There is no adjusting and readjusting for maximum power, nor adjusting and readjusting of the grid input to see its effect on the power, as all these are determined beforehand in the laboratory for a particular type of audion. The manipulation is reduced to two adjustments in addition to that of wave-length, and the proper value of these are determined with a d-c., instead of a hot-wire, ammeter. It makes no difference what type of oscillator circuit is used, or what the frequency of the oscillator is to be; any oscillator adjusted on this principle by means of the space and grid currents will be operating just as efficiently as any other oscillator with the same values of variables—E_b, R_1, I_a, I_b, and I_c It makes no difference whether the antenna circuit has high or low resistance, with these adjustments the same, the audion will deliver just as much power to one oscillation circuit as to the other. If a failure to secure as much power in one case as another occurs, it is because phase displacements in the oscillator are causing it to approach a non-oscillatory point. Such phase displacements are caused by too much leakage reactance, too small values of plate and grid choke coils, or too small values of stopping condensers. If the circuit is proportioned right the above adjustments hold.

35. Adjustments for Multitube Oscillators

When several audions are used in parallel, the adjustment is similar to that for one audion but the grid and space currents are different. The output impedance of several audions in parallel varies inversely as the number and unless a readjustment in coupling is made little change in power occurs. For the determination of values of the circuit constants, grid resistance, space current, grid current, and power, the same curves can be used as for single audions, if proper regard is taken for the connecting of them in parallel. If one audion uses a grid resistance of 10,000 ohms, using two will require 5000, three 3333, four 2500 ohms etc., at which time the space and grid current *per audion* will be the same as for one audion at 10,000 ohms. The power output of the audions in parallel under these

conditions is the same per audion as for one at 10,000 ohms. If the grid resistance for an oscillator with one audion is 10,000 ohms and more audions are put in parallel without changing the grid resistance in an inverse proportion, the power per audion will fall off. Two will not produce twice as much power as one, and three will not produce three times as much power as one. The use of several in parallel requires a change in plate and grid coupling to make the impedances attached to those members vary in the same way. The adjusting

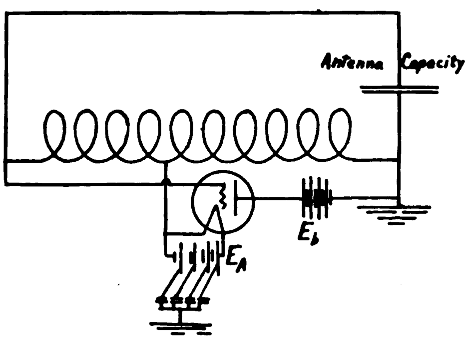

FIG. 73—HOW CAPACITY OF A BATTERY SHUNTS PART OF ANTENNA INDUCTANCE

plate and grid currents *per audion* are to be found from the curves already given Figs. 53 and 54 for the equivalent grid resistance *per audion* in the set.

36. LIMITATIONS IN THE USE OF VARIOUS CIRCUITS

The type of oscillator circuit to be used depends upon the place in which it is to be used. If it is to be used only in the laboratory where all elements of the circuit are under control, the Hartley circuit has many advantages. If it must oscillate into an antenna, the Colpitts or Meissner circuits are preferable. The Hartley cir-

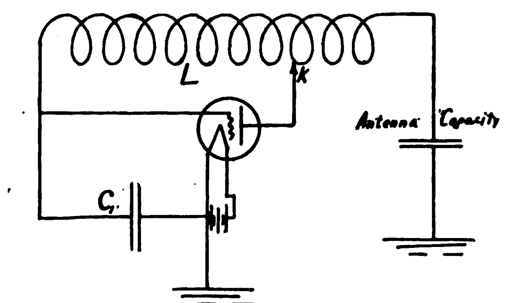

FIG. 74—COLPITTS CIRCUIT CONNECTED TO AN ANTENNA

cuit can have its frequency varied over its entire range by varying the condenser alone, and the other adjustments at all times remain practically constant. This is because the resistance of the fixed inductance rises as the frequency does but the mutual reactance $M\ \omega$ also rises and keeps the attached impedances approximately constant. However the Hartley circuit is unsuited for working into an antenna. In the first place the antenna is the capacity in the oscillation circuit and its effective value increases as the frequency does. The frequency would have to be varied by a series condenser or by decreasing the inductance. The former is undesirable on account of its inefficiency. The latter is all right but necessitates changing couplings. In the second place, one side of the antenna capacity is the ground. Ordinarily the filament supply source for the audion is grounded or has a large capacity to ground and this would produce a troublesome, if not prohibitive, capacity around a part of the antenna inductance see Fig. 73. This could be avoided by connecting choke coils in the filament leads but such coils would be bulky and wasteful of power. The Colpitts circuit avoids this latter trouble since one of the capacities used is the antenna and its ground side is connected to the filament. The filament is then actually grounded and capacity to ground gives no trouble.

The objection to the Colpitts circuit is that it is necessary to change C_1, L, and coupling K Fig. 74 in making a readjustment. Such changes can be made by a gang switch at one operation, in which case the operation of a set is simplified. For actual use on antennae, this circuit has a wider use than any other.

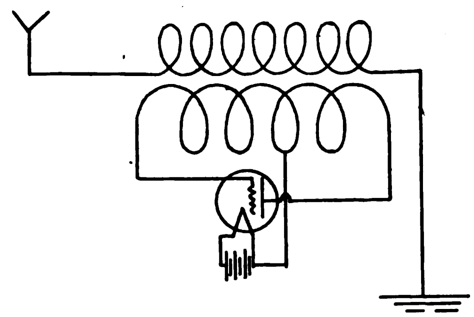

FIG. 75—MEISSNER CIRCUIT CONNECTED TO AN ANTENNA

The Meissner circuit has all the good points of both the previous circuits but it has one bad point. It is shown in Fig. 75 connected to an antenna. This circuit can be adjusted so that varying the antenna inductance alone will carry it over its entire frequency range. The only difficulty is in the proper initial adjustment. The plate-grid capacity together with the coupling coil forms a Hartley type circuit which often produces its own frequency instead of that of the antenna circuit. This can only be avoided by proper proportionment and adjustment.

For very short waves on antennae, the reversed feed-back circuit Fig. 18 is most satisfactory. This circuit cannot be used if the coupling to the plate is of the order of half the total antenna inductance or less. In such cases, a parasitic oscillation is produced due to grid-plate capacity and the attached inductances. For this reason it is non-usable at medium and long wavelengths with the average antenna.

37. CONCLUSION

This paper, it is realized, does not cover the field of the audion oscillator anywhere near completely. To do so would require several times as much space as is

used and would not add important matter in the same proportion. The curves given are for an average audion of a certain type and largely for certain adjustments in the circuit. To cover completely the oscillator's behavior would require many other sets of curves based on other adjustments. Many of these curves would be of entirely different shape and point to entirely different conclusions. However as the oscillator is more important as a generator of high frequency power than as a mere generator of sustained oscillations only the set of curves based upon maximum power has been given.

The use of other makes of audions does not alter the fundamental facts covering the oscillator's behavior. Sets of curves for them will have the same general shapes but of course will give different maxima. Other oscillator circuits may be used but they produce the same curves unless phase displacements are introduced. Such circuits will not deliver the power that proper ones will and they have been omitted.

ALASKA DEVELOPMENT BOARD

Legislation has been drawn up proposing an Alaskan Development Board to be composed of three persons appointed by the President.

The Board is to have all authority now being exercised in Alaska by existing executive departments and commissions, that is—"the Board is to have jurisdiction and control over the care, use and disposition of all reserved and unreserved public lands, including forests and waters and resources therein, . . . mines, minerals and mining." It is to be under the general supervision of the Secretary of Interior and any decision made by the Board may be appealed to the Secretary of Interior.

The members of the Board are to reside and maintain their branch offices in the territory of Alaska. The salary of the chairman is to be $8,500 and the other members are to receive $8,000 annually.

This bill is in line of recent statement of the former Secretary of Interior, Franklin K. Lane, who called attention to the urgent need of such a Board for Alaska.

ELECTRIFICATION OF FIRST MAIN LINE ROAD IN SOUTH AMERICA

A contract amounting to nearly $2,000,000 for the electrification of the first main-line railway in South America has been awarded to the International General Electric Company.

The electrification is over the line of the Paulista Railway Company between Jundiaby and Campinas, Brazil, a distance of 45 kilometers or about 28 miles. But since the road is of double track construction the total mileage, including switches and extra track, amounts to 76 miles.

The equipment to be supplied by the company consists of 12 locomotives, 8 freight and 4 passenger engines, material for the transmission line and substation and a 3000-volt overhead construction of the twentieth century type.

This project anticipates further extensions amounting to 100 additional miles of route which may eventually bring the total electrification up to 128 miles extending between Jundiaby and San Carlos.

Power for the operation of the lines will be supplied by the Sao Paulo Light and Power Company at 88,000 volts, 60 cycles.

The locomotives will be of the geared type, 3000-volt direct current. The freight locomotives will weigh 100 tons each, all weight on driving axles, and the passenger engine 120 tons, equipped with two axle guiding trucks at each end. They will be built at the Erie Works of the General Electric Company. All of them will be equipped with regenerative braking apparatus. The design of the new equipment in fact will parallel closely the Chicago, Milwaukee and St. Paul electrification, while the locomotives will be almost the duplicates of those used so successfully on the Butte, Anaconda & Pacific Railway, except for slightly increased weight and the addition of regenerative braking.

It is expected that the new line will be in operation in July 1921.

MORE SURPLUS WAR EQUIPMENT FOR ROAD CONSTRUCTION

The Post Office appropriation bill carried a provision whereby tractors may be lent by the War Department to the States for use in highway construction. When the conferees finally agreed to this provision the Secretary of War was vested with authority to use his discretion in lending such tractors as could be spared for road construction work. All expenses for repairs and upkeep as well as loading and transportation charges are to be paid by the State.

The Reavis Bill, H.R.13329, is also favorably reported. This provides for transfer of additional machinery and equipment to the Bureau of Public Roads for use in highway construction, and will permit of the use of mobile machine shops and other similar Army equipment by the Bureau of Public Roads. The committee report points out the need for suitable storage facilities for road building equipment, which is to be so used.

The Department is given authority to use its funds to provide these needed storage facilities.

According to reports recently submitted by the Bureau of Roads, this equipment will be very acceptable and will be immediately put to good use.

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with which is incorporated the PROCEEDINGS of the A. I. E. E.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

ANNUAL MEETING A. I. E. E. NEW YORK, MAY 21, 1920

Business Meeting

The annual business meeting of the A. I. E. E. will be held in the auditorium of the Engineering Societies Building, New York, on Friday, May 21, 1920, at 8:30 p. m. The Board of Directors will present its annual report for the fiscal year ending April 30, 1920. This report contains a summary of the work of the various committees during the year.

The Committee of Tellers will present its report on the election of officers for the coming administrative year, beginning August 1st.

Edison Medal Presentation

The presentation of the Edison Medal will follow immediately after the business of the annual meeting. The Edison Medal for 1919 was awarded, as announced in the January JOURNAL, to Mr. W. L. R. Emmet "for inventions and developments of electrical apparatus and prime movers." President Calvert Townley will preside at the presentation, the tentative program of which is as follows:

1. The Edison Medal, by Carl Hering, Chairman, Edison Medal Committee.
2. Achievements of W. L. R. Emmet, by Past-President H. W. Buck.
3. Presentation of the Medal, by President Townley.
4. Response, by W. L. R. Emmet.

Ladies are cordially invited to attend this meeting.

PACIFIC COAST CONVENTION

The ninth annual Pacific Coast Convention will be held in Portland, Oregon, July 21-23, 1920, under the auspices of the Portland Section.

The program is not complete as yet. Details as to the papers and authors, entertainment features, etc., will be contained in future issues of the JOURNAL.

Upon recommendation of the Portland Section officers and Vice-President Fisken, the following Pacific Coast Convention Committee has been appointed by President Townley: R. M. Boykin, Chairman, O. B. Coldwell, Wm. J. Cottrell, R. L. Elder, L. G. Fear, Lee W. Going, W. C. Heston, W. F. Hynes, A. H. Kruel, R. F. Monges, A. S. Moody, C. P. Osborne, E. D. Searing, W. S. Turner, Carl L. Wernicke, E. F. Whitney, J. E. Yates, all of Portland; and the following Chairmen of other Sections—H. S. Evans, Denver; Markham Cheever, Salt Lake City; Clem A. Copeland, Los Angeles; R. F. Hayward, Vancouver; G. E. Quinan, Seattle; J. E. E. Royer, Spokane; W. G. Vincent, San Francisco.

INSTITUTE MEETING IN BOSTON

The 359th meeting of the A. I. E. E. was held in Boston, April 9, 1920, and was a joint meeting with the American Electrochemical Society which held its 37th general meeting April 8-10, 1920. The joint meeting on Friday was held at the Copley-Plaza hotel and there were 350 members registered, 150 A. I. E. E. members and 200 A. E. S. members. The Board of Directors of the Institute held its regular monthly meeting, Friday afternoon, April 9, at the Copley-Plaza Hotel, Boston. Present: President Calvert Townley, New York; Vice-President N. A. Carle, Newark, N. J.; Managers, Charles S. Ruffner, Wm. A. Del Mar, L. F. Morehouse, New York, Charles Robbins, Frank D. Newbury, Pittsburgh, E. H. Martindale, Cleveland, Walter A. Hall, West Lynn, L. E. Imlay, Niagara Falls; Secretary F. L. Hutchinson, New York.

Reference to the important matters discussed at this meeting may be found in this and future issues of the JOURNAL under suitable headings.

The first technical session was called to order at 9.30 a. m., President W. D. Bancroft of the A. E. S. presiding. Two papers were presented on behalf of the A. I. E. E. as follows: *Nitrogen Fixation by the Silent Discharge Process*, by C. F. Harding, and *Electric and Magnetic Properties of Iron-Nickel Alloys*, by T. D. Yensen. Thirteen short papers on behalf of the A. E. S. were also presented at this session.

At the invitation of the General Electric Co. a visit was paid to the Lynn works of the company, for which special cars were furnished. A party of 250 made the trip to Lynn where the members in several groups were taken by different routes through the turbine department, motor department, meter and instrument departments. One of the features of interest was an electric furnace in full blast. The party returned to the Copley-Plaza at 5.45 p. m.

At 6.30 p. m. a subscription dinner was served at the Copley-Plaza which was attended by 125 members and guests.

The evening session convened at 8.30 p. m., President Calvert Townley of the A. I. E. E. presiding. The three papers presented on behalf of the A. I. E. E. were as follows: *Power for Electrochemical Plants* by John C. Harper, *Automatic Control of Arc Furnace Electrodes*, by John A. Seede and *Reactors for Electric Furnace Circuits*, by H. H. Winne. The session closed with the presentation and discussion of several papers by the A. E. S.

THE GREENBRIER, AT WHITE SULPHUR SPRINGS, W. VA.

36th A. I. E. E. ANNUAL CONVENTION AT WHITE SULPHUR SPRINGS, W. VA.

The 36th Annual Convention of the American Institute of Electrical Engineers will be held at "The Greenbrier," White Sulphur Springs, W. Va., June 29-July 2, 1920.

In the selection of White Sulphur Springs the Convention Committee believes that it has taken the first step toward making this year's convention one of the most successful of Institute affairs. White Sulphur Springs has a peculiarly attractive environment on the south slope of the Greenbrier Mountains, 2000 feet above sea-level, where it is never hot, even in mid-summer. The Greenbrier itself is a new and magnificent hotel of modern steel construction, absolutely fireproof and is equipped with every convenience. Every room has lavatory and toilet arrangements and is connected with a private bath. For those desiring quiet, there are 60 small cottages surrounding the hotel. Members will find that one of the chief charms of White Sulphur Springs lies in the ability to find things to do. There is an 18-hole golf course, 6250 yards long, one of the finest in the country, and an equally good nine-hole course. The new clay tennis courts are famed the country over. The new bath establishment is luxurious and complete. Every facility is offered guests to enjoy the same kind of baths as are given at European resorts. There is a fully equipped swimming pool, 50 by 100 feet. Over 100 miles of well built track winding in and out through the mountain ridges lead those interested in horses and riding through some of the most beautiful scenery in the State. A fine stable is maintained, with thoroughbred hunters, jumpers, and horses for all occasions and there is a pack of hounds for drag hunts. Those interested in motoring will find the roads leading through White Sulphur Springs in excellent condition and motoring from New York, Philadelphia and Washington is steadily increasing.

In distinction to the Midwinter Convention of the Institute which is almost entirely devoted to the presentation and discussion of technical papers; the Board of Directors in conformity with a policy adopted years ago, that the Annual Convention program should be so arranged as to provide opportunity for those attending to increase their circle of Institute acquaintanship through association in recreation, has requested the Meetings and Papers Committee to confine the technical sessions to the mornings, leaving the afternoons and evenings available for events to be arranged by the Convention Committee, or otherwise as the individual members and guests may desire.

A tentative program has been arranged which will call for the opening of the Convention with the presentation of the President's Address followed by the Technical Committee Reports. Six sessions under the auspices of various technical committees have been mapped out as follows: Electrical Machinery Committee, B. A. Behrend, Chairman, Symposium on "Temperature Conditions Prevailing Inside Large A-C. Generators," with papers by Philip Torchio, B. G. Lamme, W. J. Foster, C. J. Fechheimer and F. D. Newbury, and R. E. Gilman.

Protective Devices Committee, D. W. Roper, Chairman, papers by C. P. Steinmetz, F. H. Kierstead, H. B. Dwight, and B. Gross.

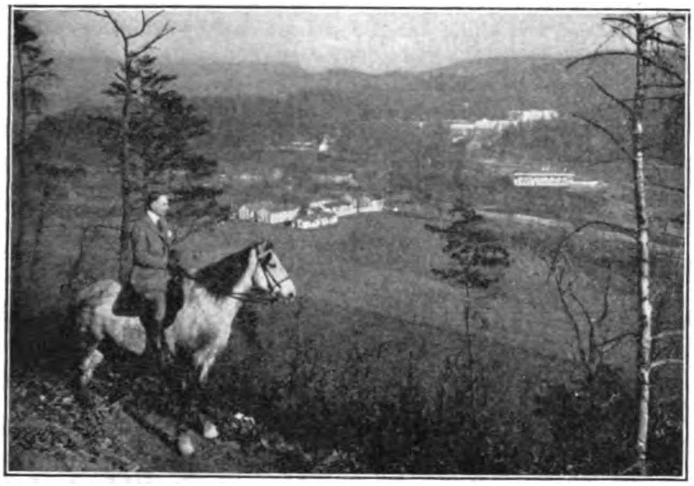
Special Committee on Determination of Power Factor, S. G. Rhodes, Chairman, report of committee and papers by Messrs. Holtz, Brown, Pratt, Silsbee, Wallau, Fortescue and Torchio.

Electrical Machinery Committee, B. A. Behrend, Chairman, session on Welding with papers by Messrs. Hansen, Bergman, Churchward, Candy, Turbayne and Miner.

Power Stations Committee, Philip Torchio, Chairman, Symposium on "Excitation," with papers by Messrs. Bauhan, Ross, Vogel and others.

Miscellaneous session with the following papers; "A-C. Commutator Motors" by J. I. Hull; "High-Tension Insulator Porcelain" by W. D. Peaslee; "Reactive Power and Magnetic Energy" by J. Slepian and "The Corona Voltmeter II.," by J. B. Whitehead and T. Isshiki.

The Convention Committee, appointed by President Townley, and which is charged with the duty of making all necessary arrangements for the convention, in addition to the technical sessions arranged by the meetings and Papers Committee as outlined above, is composed as follows: Messrs. John H. Finney, Washington, D. C. (Chairman), Walter A. Hall, F. L. Hutchinson, Farley Osgood, Chas. Robbins, A. M. Schoen and W. I. Slichter.



A BIRDSEYE VIEW OF THE GOLF LINKS AND THE WHITE SULPHUR SPRINGS RESORT

A complete program will appear in the June JOURNAL giving authors and titles of all papers, details regarding section delegates conferences, entertainment features, hotel and railroad rates, etc. This information will also be mailed to the Institute membership in circular form.

FUTURE SECTIONS MEETINGS

Erie.—May 17, 1920. Professor V. Karapetoff.

Ithaca.—May 21, 1920. Subject: "High Tension Insulators." Speaker: Mr. A. O. Austin, Engineer, with the Ohio Insulator Co.

Milwaukee.—May 19. 1920. Subject: "Coming Science of Acoustical Engineering." Speaker: Professor V. Karapetoff.

Philadelphia.—May 10, 1920. Students' Night. Subject: "Professional and Financial Aspects of Electrical Engineering."

June 7, 1920. Annual Meeting. "Howard McCall Field." A day in the open air; sports.

St. Louis.—May 26, 1920. Mr. Beck, of the Southern Illinois Public Utilities will speak before the Section.

San Francisco.—May 28, 1920. Railway Electrification Committee Report.

Washington.—May 11, 1920. Annual meeting; election of officers.

APPEAL OF AUSTRIAN ENGINEERS

Fellow Craftsmen: Austria is hungry! The supply of foodstuffs available is less than half enough. Hunger has lowered the standard of our work and has undermined us so physically that we can do nothing toward improving ourselves. We turn to America as the only state which can help us in our distress; the only nation in the world that can keep us from starving.

There are 1000 members in our organization in Austria in the various branches of Engineering, such as Electrical, Mechanical, Civil, Mining, Architectural and Chemical. Approximately half of our members are wholly without employment, but even those who have work receive only on an average of 1500 kronen a month, a little more than $5.00.

Through the American Relief Administration a means is provided for furnishing us with food. Americans can buy food drafts at any bank in America and send them to us by registered mail. On presentation of these drafts in Austria the American Relief Administration Warehouse will deliver to us stipulated quantities and kinds of American food shipped to Austria for that purpose. The American Relief Administration has had post cards printed to be sent to relatives and friends in America. These cards tell how you can help us. We guarantee that all food received from food drafts sent to us from America will be distributed equitably among our members under direct supervision of the American Relief Administration representatives in Austria.

You are our professional brothers—and we ask you to stand by us in our hour of need. We appeal to you, fellow craftsmen, across the sea to send us food drafts, lest we starve!

Address:
Gewerkschaft der Ingenieure in Privatdienst,
Wien, VI, Kostlergasse 7, Mezz. links.

April 10, 1920.

Charles F. Rand, Esq.,
71 Broadway,
New York City.

Dear Mr. Rand:

You have, I know, interest in our Food Draft scheme, and I wonder if you can help me out. We find that the needy population in Austria is largely concentrated in Vienna. There are very few Austrians in America who can claim affiliation in the present restricted area of that country, and as a result few Food Drafts are issued in America to friends and relatives. This means that the people are largely dependent upon finding new friends or associations to whom they can appeal. As a result, various associations and societies in Austria are appealing to similar organizations here.

As an instance, the medical men here have banded together to support the medical men in Vienna. The firemen of New York are buying Food Drafts for the firemen of Vienna. The Geological Survey is arranging for the purchase of Food Drafts for the geologists over there, and so on.

Now comes through a letter from the "Society of Engineers in Private Service." This organization includes electrical, mechanical, civil, mining, and mechanical engineers, and architects. These men are in private employ and not in government employ, and are in extremely bad circumstances. They have sent me six copies of a letter which they desire to put into the hands of these various societies here.

Very truly yours,
s/d EDGAR RICKARD,
Acting Chairman,
American Relief Administration.

April 12th, 1920.

Mr. J. Parke Channing,
Chairman, Engineering Council,
61 Broadway, New York.

Dear Sir:—

I wish to give my endorsement of the project of endeavoring to sell food drafts among our engineers for the benefit of the engineers in private practise in Austria.

If you feel willing to add your approval I suggest that you transmit the papers to Mr. Flinn and request him to endeavor to arrange for the publication of this appeal in the monthly journals of the several engineering societies.

Very truly yours,
s/d CHARLES F. RAND,

April 13th, 1920.

Mr. A. D. Flinn, Secretary,
Engineering Council.

I herewith enclose you five identical letters, all originals, from the Austrian "Society of Engineers in Private Service," together with a letter from Edgar Rickard to Mr. Rand, and one from Mr. Rand to me.

It goes without saying that anything of this character which has the endorsement of Mr. Hoover should be given most serious consideration. I am prepared to give my approval to it and I would suggest that you transmit these copies to the Secretaries of our various constituent societies, together with copies of the letters from Messrs. Rickard, Rand and myself.

Yours truly,
s/d J. PARKE CHANNING,
Chairman.

AERONAUTIC CONGRESS, ATLANTIC CITY, N. J., MAY 20-30, 1920

The third Pan-American Aeronautic Congress will be held under the auspices of the Aerial League of America at Atlantic City, N. J., May 20-30, 1920. In connection with the Congress an engineering conference will be held to discuss important phases of aeronautic engineering, including the illumination of airplanes and aviation fields.

A cordial invitation has been extended to the membership of the American Institute of Electrical Engineers to attend this Congress and the engineering conference.

ENGINEERS MEETING IN CHICAGO APRIL 19-20

Some months ago the governing body of the Western Society of Engineers, of Chicago, extended an invitation to the governing bodies of the National Societies of Civil, Mining, Mechanical, and Electrical Engineers to hold a joint meeting in Chicago during the month of April, for the general purpose of discussing the interests of the engineering profession. This plan was carried out and the following brief statement has been received as we are about to go to press:

A dinner to which the engineers of Chicago and their wives were invited, and which was also attended by the members of the governing bodies of the five societies mentioned above, was given at the Hotel La Salle on Monday evening, April 19. Mr. A. Stuart Baldwin, Past President of the Western Society of Engineers, presided; and brief addresses were made by the Presidents of the other four societies, followed by an address on "Efficient Democracy" by Dr. Lynn H. Hough, President, Northwestern University.

On Tuesday, April 20, there was a luncheon at the University Club attended by the members of the governing boards, and the executive committees of the Chicago Sections, of the above named societies.

Both of the joint sessions referred to were exceedingly interesting and profitable to all who attended; and this joint meeting will undoubtedly be of general benefit to the entire engineering profession.

ENGINEERING FOUNDATION BOARD

At a meeting of Engineering Foundation Board held on March 19, 1920, the resignation of Dr. W. F. M. Goss, Chairman of the Board, dated February 14, was accepted with regret and appreciation of his able services. On nomination of the Executive Committee, Charles F. Rand was elected Chairman for the term ending at the annual meeting in February 1921.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

SIXTH MEMBER SOCIETY

The American Railway Engineering Association has accepted an invitation from United Engineering Society to become a member society of Engineering Council. The Association has about 1650 members and its headquarters are at 431 South Dearborn Street, Chicago, Illinois. Its President is Mr. Harry R. Safford, and its Secretary Mr. E. H. Fritch. The excellent technical work done by the committees of this Association in many branches of railroad construction and maintenance are well-known.

The Association has named as its representative upon Engineering Council its President, Mr. Safford, who is a member of the American Society of Civil Engineers and Engineering Institute of Canada. He was recently appointed Assistant to President Hale Holden, of the Chicago, Burlington and Quincy Railroad Company, the Colorado and Southern Railway Company, the Fort Worth and Denver City Railway Company, and The Wichita Valley Railway Company. He was formerly Chief Engineer of the Grand Trunk Railway, and is well known in Canada, as well as in the United States. Following the severance of connection with the Grand Trunk, he became Assistant to the Regional Director, U. S. Railroad Administration, Chicago.

The Societies now represented in Engineering Council have an aggregate membership of 45,000.

KEEPING TAB ON FOREIGN MARKETS OF INTEREST TO ENGINEERS

The Government through its Bureau of Foreign and Domestic Commerce keeps in very close touch with conditions in foreign markets, construction work in foreign countries, and other items which will be of distinct value to American engineers to know about in the conquest that is already well started for world trade.

The Daily Consular and Trade Reports afford a good field for keeping in touch with many items that engineers in the manufacturing, construction and consulting fields will want to know more about. A few of the subjects which have been reported since the first of March are itemized below and in addition to these, a list of foreign trade opportunities touching every field of commerce is maintained in the Department of Commerce and daily supplements to this list are published.

In addition to putting engineers in touch with these reports and the list of foreign trade opportunities, the National Service Department of Engineering Council hopes to be able to build up definite contact with the national engineering organizations similar to Engineering Council or at least functioning in the same field in all important countries. This it is hoped will open much valuable information to American engineers and eventually give foreign engineers the advantage of keeping up with American engineering progress. By this means it is hoped that the engineering profession can be of the greatest service to the country in building up world trade.

World's ocean passenger ships, March 1st. Gasoline Situation in British Isles, March 3rd. Swedish market for telephone apparatus, March 3rd. Market for motor trucks in Canary Islands, March 3rd. Iron and steel industry of Hungary, March 4th. The Belgian steel and metal industry, March 4th. German war industries in peace times, March 4th. Swedish demand for American machinery, March 4th. Machinery trade of the Canary Islands, March 9th. French resources of iron ore, March 9th. Plans for development work in Belgian Kongo, March 9th. Increasing demand for electrical goods in Canada, March 12th. Limited fuel-oil supply in

Argentina, March 16th. British output of iron and steel in 1919, March 17th. Steel situation in Great Britain, March 18th. Italy makes large appropriations for public works in Sardinia, March 18th. Iron and steel situation in Canada, March 18th. Need of railway locomotives in Italy, March 18th. Fuel oil for motive power on French railways, March 20th. Decreased Government stock of metals in Great Britain, March 22nd. The metric system in Belgium, March 23rd. Electrification of South African Railways, March 23rd. Iron and steel development in Brazil, March 24th. Japan's machinery imports, March 26th. Exhibition of American products in Buenos Aires, March 31st. New International chamber of commerce, March 31st. Telephones in Bulgaria, April 6th. Additional refrigerating facilities for Italy, April 6th. Credits necessary in selling machinery to France and Belgium, April 9th.

MAIL TUNNEL SYSTEMS FOR LARGE CITIES

When the Senate and House conferees agreed on the Post Office appropriation bill, it contained a provision for a commission, which is to study among other things, the advisability of establishing a system of tunnels to handle mail in congested centers,—especially in New York City.

The commission is to consist of a chairman and four members of the Committee on the Post Office and Post Roads from both the Senate and the House and a postal expert appointed by the Postmaster-General. This commission is to have authority to appoint an advisory council of seven to be composed of those having special knowledge of the work in hand,—preferably representatives of commercial organizations, and engineers who are acquainted with existing conditions and requirements. Further, the commission is authorized to employ such engineers and special experts as it is deemed necessary to assist in its investigation.

The appointment of the advisory council to this commission is in line with the recommendations that Engineering Council has made to the Post Office Committee of Congress. It is especially fitting that this legislation should carry special provision for the use of engineering opinions in the accomplishment of a joint congressional committee's work.

SENATE PATENT HEARING

Another very satisfactory hearing has been given representatives of Engineering Council's Patent Committee and representatives of the Patent Committee of the National Research Council, this time before the Senate Patent Committee.

Following a statement by Mr. Edwin J. Prindle, chairman of Engineering Council's Patent Committee, concerning the large body of representatives of various organizations present, Senator Morris, Chairman of Patents Committee, asked if there was anyone who appeared in opposition to the Nolan Bill. From among seventy or more representatives present, no word of opposition to the general bill was heard.

The amendment to Section 7 of the bill which provides recoveries for infringement, was contested and through questions asked by the Senate committee, it was brought out that such a provision could not be made to apply to present litigations—in such cases this amendment would be simply an interpretation of existing law.

Every witness whether in favor of the provisions in the amendment or not urged that immediate action be taken on the Nolan Bill as originally written in order that immediate relief could be had in the way of increased force and salaries of the Patent Office. The Senate committee agreed to discuss the effect that the amendment would have with members of the House Patent Committee and to take such action as would insure immediate and favorable final action on the Nolan Bill.

NEW RAILROAD CLASSIFICATION OF SUBORDINATE ENGINEERS

The Interstate Commerce Commission has held lengthy hearings on the classification of engineer assistants in the railroad employ, and as a result has issued regulations classifying subordinate officials as provided in the Transportation Act.

These engineers are grouped into a class as "Engineers of Mechanics." This class includes civil engineers, inferior in rank to engineers of maintenance-of-way, chief engineers or division engineers. It includes draftsmen, engineers on maintenance-of-way work, and other engineers of mechanics, who are not vested with authority to employ, discipline or dismiss subordinates.

Representatives of the American Association of Engineers, whose membership includes many engineers in this class, presented arguments in favor of a separate grouping for subordinate technical engineers. It was shown that twenty thousand technical engineers in the employ of the railroads would be included in such classification, whereas only five per cent of that number are engineers that come within the category of executives. No other class of railroad employees has a more trusted relationship with their companies than do the subordinate engineers, assistant engineers, architects, rodmen, chainmen and draftsmen. Because of the fact that this class of engineers has previously had no classification it has received practically no consideration from the railroads in the point of increases in salary, promotion schedules, etc. For the same reason, also, it has been hard for engineering organizations representing this class to obtain improved conditions.

It will be recalled that the Engineering Council went before the old Board of Wages and Working Conditions under the Railroad Administration to assist in getting a classification and increased compensation for the men who have now been classed "Engineers of Mechanics." Some good was accomplished but conclusive results could not be obtained because this group of engineers was not then known as a unit on the Railroads.

CLASSIFICATION AND COMPENSATION OF ENGINEERS

Arthur S. Tuttle, chairman in an address before the American Association of Engineers, Chicago, discussed the work done by the Committee on Classification and Compensation of Engineers. Extracts from his remarks follow, which will add to the records of this activity of Engineering Council that have been printed in preceding issues of the JOURNAL:

A little over three years ago a general investigation of engineering compensation was completed by the American Society of Civil Engineers, from the report of which it appeared that compensation for engineering service compared favorably with that in other professions. Subsequent rapid decrease in the value of the dollar and corresponding lowering of morale led Engineering Council about a year ago to study those branches where compensation was admittedly lowest and where the needs were more pronounced.

A committee was appointed, which held its first meeting April 24, 1919 and to the close of the year the investigation drew heavily upon the time of those engaged in the study. To establish a basis of comparison, to the end that all engineers could be measured as to responsibility on a common basis, a general classification was attempted. A comprehensive nomenclature for service grades was unanimously agreed upon by the Committee and adopted by Engineering Council December 18, 1919; also a further recommendation that this classification be recommended for general use in every branch of the profession. Under it engineering service is to be separated into Professional and Sub-Professional, the former comprising five grades and the latter three, to include in the former only men holding a professional degree or men who have had four years' experience in the Sub-Professional service and who have supplemented this

experience by mastering engineering principles and equipping themselves with the basic essentials for advancing through higher grades. It is also proposed to require education equivalent at least to graduation from a high school for admission to the Sub-Professional service, thus insuring that those who enter it possess the essentials on which to build their further training, and also clearly separating this service from the labor class and placing it unmistakably on a higher plane.

Heretofore efforts in the direction of securing adequate compensation have been handicapped in part by the absence of any well-defined basis for comparison of positions and in part by the unwillingness of engineers to discuss this subject publicly lest such discussion might tend to lower professional pride and dignity. The financial advantages to the capitalistic class through the shortages growing out of the great war and the success of labor in its vigorous efforts to share in these benefits have apparently led engineers to substitute for "the Lord will provide" as an accepted theory a belief that "God helps those who help themselves."

Previous inquiries have been addressed to the individual directly concerned, which involved the collection of a vast mass of data colored by the personality of each respondent. The magnitude of the field, the need for haste, and the desire to get the best valuation available, led the Committee to seek returns from responsible service heads. The advantages of the adopted plan seemed so obvious that the general character of the questionnaire was never made the subject of other than brief discussion. The investigation included the securing of data as to compensation for July 1, 1915 and of July 1, 1919, the former date marking the beginning of the rise in wholesale prices of commodities in common use.

The State and Municipal inquiry was directed to State Engineers, State Highway Engineers, Chief Engineers of State Commissions charged with large engineering undertakings, and City Engineers of the 69 cities having a population of over 100,000. In all 191 services were approached; from 101 of these, returns were received. The entire returns included 2,222 men in State and 3,317 in City service. It is estimated that the sereturns comprise over one-half of the engineers in State service and about two-thirds of those serving municipalities.

Comparing the position returns for the Municipal service with those for this service as a whole, it appears that about 6 per cent of the increased compensation reported has been an incident growing out of promotion to higher grade, which would seem reasonable under normal conditions.

The average age of men in all grades of the State service is much lower than in the corresponding grades of Municipal service, this being probably due in part to the fact that many State services have been organized at recent dates. It also shows that average present compensation for the higher professional grades in Municipal service is much above that in the State service, as is the compensation recommended, and that the present as well as the recommended rates for the lower grades are generally much alike in both services.

Considering the average present compensation reported for the various positions, in the professional service, (these comprising 86 per cent of the total number of engineers concerning whom data have been obtained) the average compensation is less than $2,200, or the estimated cost of living for a moderately small family, and the average compensation for even the highest grades is utterly incommensurate with what might reasonably be expected, particularly when compared with rates generally charged by engineers not in public service.

From the latest statistics available it seems probable that the cost of living is about 80 per cent more than in 1915. This, however, is not to be regarded as the basis for the recommendations of the Committee, which are intended to insure to the young unmarried man an income sufficient on which to live, and to provide compensation for men in the higher grades sufficient not only to make up the increased cost of necessaries, but also designed to provide for recognition of value not heretofore given. It is conceded that men drawing the major salaries should be the ones to make the sacrifices required to meet the war expense. An argument for increasing their pay in the same or greater proportion as for the men living on the lowest living wage would be fallacious if based on the decreasing value of the dollar. In this case the advance proposed is on the ground that it gives the engineer that to which he is entitled but which has heretofore been withheld. By increasing at the top the way will be automatically opened for extending recognition to all grades. Only by such recognition can real relief come to those who have devoted themselves to professional service and who, by reason of the limitation of room, cannot find a place at the very top, but who by proven worth have demonstrated their value and their fitness to assume the large responsibilities placed on them.

The needs of the lower grades of service have now been met to some extent, and if the profession as a whole could unite in a movement to endorse every effort put forth to raise the compensation of chief engineers, the remainder of the problem would be easy to solve. To secure permanent improvement and attract to and retain in the profession the best men, it is desirable to fix pay at entrance at a rate such as not to bring in men who are without engineering education or who have no natural leaning along engineering lines. Men admitted to the service should be denied advance unless decided merit is shown, in which case promotion should be certain and liberal. In this way standards can be raised and the mediocre men will not remain as a handicap to the progress of those more worthy. Before engineers can reach the very highest places in administrative work, they must cultivate an increased breadth of view and accept more responsibility; they must give the business side of undertakings with which they are connected the same thought that they devote to the technical features.

While the suggested increases in compensation would apparently aggregate a vast sum, it is the belief of Engineering Council's Committee that the increase would be more apparent than real as it seems safe to assume that through a restoration of morale with consequent increase in efficiency, through the weeding out of incompetents, and through the certain saving resulting from better design and construction, the total expense would be less than under present conditions.

It cannot be questioned that the long period of comparative inactivity in railroad construction and the return of the roads to their owners must be followed by a revival of enterprises of vast magnitude. The comparative freedom from governmental red tape which will now be enjoyed should open up a brilliant prospect to men in this service, and the speaker sincerely trusts that in the new era about to dawn his professional brethren who have in the past devoted themselves to this branch of engineering will realize their long deferred hopes for the day when members of this profession will find a proper financial reward for their services.

CURRENT ENGINEERING TOPICS

A SUBSTITUTE FOR THE METRIC SYSTEM

A measure providing decimal divisions of the English system of weights and measures has been introduced as a substitute for the proposed compulsory metric system. Advocates of this substituted measure claim that it affords all the advantages of decimal notation, which they claim to bethe only merit of the metric system, and at the same time preserves the convenience, facility and utility which are inseparable from the accustomed measures of length and weight in this country. All that is claimed for this bill is that it will tend to help in the improvement and development of our present system. Engineers who considered this new legislation are of the opinion that it would only

complicate the present usage of our divisions of weights, measures and coins without adding materially to the improvement of our present system.

WATER POWER BILL

The Water Power Bill conferees have reached agreement on all points of difference except the provision limiting certain allowances for severance damages on recapture of franchise at end of the fifty year period. The Senate has receded from its amendment directing the assignment of an army engineer as secretary of the Commission and has left this appointment to the discretion of the Commission.

WAR MINERALS—COURT OF CLAIMS

When it became apparent that the new War Minerals Relief Bill would have the opposition of Congressional leaders, the chairman of the House Committee on Mines and Mining decided to make substantial changes in the measure. The Committee on Rules will be asked to give the new bill a special place on the calendar.

Congressional leaders are trying to cut Governmental expenses in every way possible and they realize that the provision giving authority to the Court of Claims to hear war mineral cases "de novo" would entail large additional expenses over a long period.

Under the provisions of the new bill, however, these conditions are made worse, because it provides that claimants shall have the right of appeal from the Court of Claims through the Supreme Court of the United States. It also relieves claimants from the obligation to execute a bond to protect the Government against reduction by the Court of Claims of any award which may have been already made. In other words, it permits a claimant to accept whatever award the Commission shall recommend, and, without more than nominal cost to himself, appeal to the Court of Claims for more. Also, to guard against the Court of Claims requiring that the ordinary rules of evidence shall apply, it provides that the testimony already taken before the Commission may be used. The Commission has been very liberal in acceptance of testimony from claimants, much of which would not be admitted in a court of law.

To protect against such contingency, the above clause is added. It is easily to be seen that the proposed plan will offer fine business for claim attorneys but indefinitely prolong final settlement.

From the engineer's standpoint, it becomes evident that the bill in the new form will cost the Government a great deal more for its administration, as well as materially extend the time for final settlements.

PERSONAL

H. G. Harvey has resigned as Commercial Engineer of the Nassau Lt. & Pr. Co. of Mineola, N. Y., to take up similar work with the Pennsylvania Utilities of Easton, Pa.

Taliaferro Milton, formerly assistant manager of the Chicago Office of the Electric Storage Battery Company, has become manager of the same office, located at 613 Marquette Building, Chicago.

Geo. C. James, formerly of the Engineering Staff of the Habirshaw Electric Cable Company, Inc., is now connected with Chas. C. James & Company, Stock Brokers with offices at 410 Times Building, New York City.

Ralph A. Watson has left the Consolidated Arizona Smelting Company to become Chief Engineer for the Tennessee Copper Company at Copperhill, Tenn.

J. A. Obermaier, of the Illinois Testing Laboratories, Inc., announces that these laboratories have moved into new and enlarged quarters at 430 South Green Street, Chicago. Here they will be in a position to increase the scope of their work, particularly along the lines of developing new apparatus and doing an increased amount of testing and engineering work.

Henry Harvie has resigned his position as assistant to the hydraulic engineer of design, Hydroelectric Power Commission of Ontario, on appointment to hydraulic engineer with the Canadian Ingersoll-Rand Company, 260 St. James Street, Montreal, Canada.

Wm. C. Rommel, formerly rate expert for the Public Service Commission of Pennsylvania, is now in charge of an office in Harrisburg, Pa., opened by the Utilities Engineering and Accounting Company. The scope of the office will include costs analyzed, rates designed, tariffs prepared for filing, valuations, reports, accounting, engineering, and management.

J. Harvey McClure, formerly general superintendent of the Citizens Traction Company, Oil City, Pa., under the management of Day and Zimmerman, Inc., Philadelphia, has been promoted by that company to the position of vice-president in charge of operation of the Ohio Electric Railway Company. This opens a large field of operations to Mr. McClure, the system having both interurban and city service in Ohio and Indiana. He has made Lima, Ohio, his headquarters. Mr. McClure joined the Institute as a Member in 1919.

W. A. Lodge, research engineer with the Bussman Mfg. Company, will be in full charge of the engineering department, devoting his time to research and the technical development of the Bus Fuse. He will also conduct the necessary tests as required by the Underwriters' Laboratories. Mr. Lodge has for the past four years been with the Underwriters' Laboratories of Chicago as research engineer. Previous to his connection with the Underwriters' Laboratories, he was professor of Electrical Engineering in two of the largest Universities in the United States and Canada.

Theo. Schou, formerly professor of Electrical Engineering at the University of Iowa, and later consulting engineer for the Electric Machinery Company, Minneapolis, Minn., is now connected with the Ideal Electric & Mfg. Co., Mansfield, Ohio, in the capacity of chief engineer. Mr. Schou has specialized in the design of synchronous motors, being recognized as one of the foremost in this field, and will develop a new line of synchronous machines for The Ideal Electric & Mfg. Co., who are enlarging their facilities to include the manufacture of this type of apparatus. During the past few years Mr. Schou has contributed a number of articles on the design and manufacture of synchronous machines to the leading technical periodicals.

W. G. Claytor has been appointed assistant to the general manager of the Roanoke Railway and Electric Company, Roanoke, Virginia, and the Lynchburg Traction and Light Company, Lynchburg, Virginia. Mr. Claytor was formerly general superintendent of the Lighting and Power Departments of the Roanoke Railway and Electric Company and the Lighting and Power and Gas Departments of The Lynchburg Traction and Light Company, having entered the services of these companies in January 1907. He was commissioned a Captain in the U. S. Army in 1918, and assigned to the Construction Division as Electrical Engineer for the U. S. Picric Acid Company, Brunswick, Georgia.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

LEADER FOR ELECTRICAL DESIGNING squad of a very old, large and reputable engineering company. Must have experience in designing electrical installations for industrial plants including power and light wiring; installation of motors, telephone, auto fire alarms, auto call systems, etc., and electrical generating plants. Location New York City. Z-1046.

ELECTRICAL ENGINEER technical man, with broad experience in the design and installation or operation of High Voltage Distribution Systems and Out-Door Sub-Stations. A good position for high grade man with well established progressive company manufacturing high voltage equipment. Give full information regarding education, experience and past connections, as well as salary expected. Location Chicago, Ill. Z-1060.

RECENTLY ORGANIZED FIRM of consulting engineers would like to hear from a graduate designing engineer who has had two or more years experience in the designing of automotive vehicles, preferably tractors or trucks. Prefer applicants who have also had machine shop experience. This opening is an exceptional opportunity for a young engineer who is willing to bend his back over the drawing board when necessary and who has a good personality. An opportunity will be offered to expand into the business end of our work. Applicant must be a natural mechanic and rapid at drafting. Location Wisconsin. Z-1061.

GRADUATE ELECTRICAL ENGINEERS for radio research work. Recent graduate will be considered. Z-1062.

RECENT GRADUATES in Electrical Engineering for our engineering sales department. Write, stating age, experience, salary expected. Communications held confidential. This is an excellent opportunity to gain a broad engineering training in a live organization. Location Rochester, New York, Z-1063.

INSTRUCTORS. An examination will be held in Sampson Hall, U. S. Naval Academy, Annapolis, Maryland, for selection of two instructors in Department of Electrical Engineering and Physics. Examination will be competitive, and candidates found qualified will be eligible in the order of merit as determined by the Board of Examiners, for appointment to fill vacancies in this department. Should more qualify than there are vacancies for at present, their names will be placed on a reserve list for later appointment to subsequent vacancies if they so desire. Appointments will be made immediately to those qualifying for the above vacancies and will thereafter be renewed annually on July 1st, provided performance of duties has been satisfactory. Salary on original appointment is $2000 and an increase of $100 is given on each reappointment. Instructors are eligible for appointment as Assistant Professors, salary $2400, after 2 years, and as Associate Professors, salary $3000 after 5 years. Appointment to Professor after 10 years, salary $3600, with 10% increase every 5 years. Candidates must be American Citizens. The age limits are 25 to 35 years though these may be waived in special cases. Candidates must have completed satisfactory professional courses in recognized colleges or universities. In grading the candidates due weight will be given to past experience, letters of recommendation, etc. The examination will be written and will cover the following subjects: (1) First year College Chemistry; (2) Elementary and Advanced Physics. (More particularly those subjects pertaining to Electrical Engineering); (3) Laboratory work to correspond to (1) and (2); (4) Principles of Direct and Alternating Current Electricity, including storage batteries, direct and alternating current machinery, elementary telephony and radio telegraphy. Blank form of application is enclosed herewith which must be filled out and returned to the Superintendent. U. S. Naval Academy, Annapolis, Md. without delay. Candidates having filled out and returned their form of application may appear before the Board of Examiners on the date above stated, without further authority. It is requested that they bring their references with them. The examination will take about 2 days. Further information furnished on application. A. H. Scales, Captain U. S. Navy. Superintendent. Z-1064.

ELEVATOR ENGINEER. Technical graduate with several years experience in elevator work. Location Pennsylvania. Z-1065.

DRAFTSMEN (ELECTRICAL) FOR PANAMA CANAL: 1 experienced underground power distribution and building illumination; 1 hydro-electric power plant designer; 1 familiar with fire control work of coast artillery, 1 marine Machinery Draftsman. Applicants must be thoroughly experienced in special lines above indicated. American citizens (final papers) under 50 years of age, in good health. Free Steamship transportation from New York or New Orleans, salary beginning date of sailing. No civil service examination required. Write Chief of Office, The Panama Canal, Washington, D. C. Z-1066.

ASSISTANT ELECTRICAL ENGINEER. Public utility located in the Middle West, furnishing electric light, power and railway service, desires a technical graduate, having had practical experience in transmission, distribution and substation work. Ability, personality and enthusiasm such as to qualify applicant for advancement in rapidly growing organization are absolutely essential. Initial salary $3000. Z-1067.

ASSISTANT ENGINEER with experience in transmission and differential work for position with company manufacturing automobile gears. Must be thoroughly familiar both with production, manufacture, and operation. Salary $250-300 per month. Location Ontario. ½ hour from Buffalo. Z-77.

YOUNG ILLUMINATING ENGINEER capable of designing show window and commercial lighting installations; selling experience desirable but by no means essential since the man selected to do designing will be assisted by competent commercial lighting salesmen. Location Tennessee. Z-260.

SERVICES OF TWO YOUNG ELECTRICAL ENGINEERS wanted, recent technical graduate preferred, for A. C. industrial control design. Splendid opportunity. Write stating education, age, nationality, salary and when available. Location Newark, N. J. Z-342.

ELECTRICAL DRAFTSMEN at starting rate of $150 to $175 per month. Duties of position involve designing and detailing in connection the planning of electrical installations in stations and substations. Location Chicago, Ill. Z-548.

INSPECTOR OF MATERIAL for service in the United States. Must be technical graduate with at least two years' experience with large manufacturing concern. Salary $150 a month plus $20 a month Congressional bonus after thirty days' satisfactory service. Applicants should write to Chief of Office, the Panama Canal, Washington, D. C. Z-609.

ELECTRICAL DRAFTSMEN and Designers for work in connection with transmission lines, substation equipment, switchboards, motor control equipment, etc. Location Ohio. Z-613.

LARGE NEW ENGLAND MANUFACTURER of electrical apparatus wants young men with some experience in drafting who desire to improve their opportunities. To such as have good high school education and some technical training but who for some reason were not able to complete their technical course, we offer opportunity to work as draftsmen

at good wages and at the same time, without expense attend courses of instruction to prepare them for positions here as calculators or designers of electrical apparatus or specialists in sales organization. Location Mass. Z-628.

EXPERIENCED SWITCHBOARD OPERATOR for hydro-electric station. Salary $115 per month, eight hours, location New England. Give experience, age, references, whether married or single. Z-678.

SALES ENGINEER; technical graduate preferred but not essential, familiar with Eastern Territory; must have experience in sale of power transmission apparatus and be familiar with factory conditions. Liberal salary and splendid opportunity to connect with a growing concern. Territory New York and New England. Z-772.

ASSISTANT ELECTRICAL ENGINEER for large manufacturer of excavating machinery. Duties will include application and arrangement of electrical equipment, such as—motors, magnetic control, transformers, motor generator sets, wiring, etc. to electric shovels, dragline excavators and dredges. Technical man with electrical and mechanical experience desired. Salary $125-175. Z-817.

ELECTRICAL ENGINEER; permanent position open for graduate engineer, preferably Canadian familiar with Ontario. Intimate knowledge of interurban electrical railway equipment and operation essential. Apply Employees Relations Department, Hydro-Electric Power Commission of Ontario, 190 University Avenue, Toronto, Canada. Z-818.

INDUSTRIAL POWER SALESMEN AND INDUSTRIAL HEATING ENGINEER; capable of assuming direct charge of district in the city of St. Louis and in that district, conducting all negotiations incident to sale of power in large blocks to new industries and conversion to Central Station energy of any isolated plants, now in existence. Men should be able to handle such negotiations with minimum of supervision. They should be graduate electrical engineers. Those having sales experience in Industrial power work are preferred. Location Missouri. New York interview possible. Z-864.

FOREMAN for testing department for magnetos and magneto generators. Department has 25-30 men. Location Brooklyn, N. Y. Z-871.

ILLUMINATING ENGINEER experienced for field work. Must have been doing this kind of work. Location New Jersey. Z-872.

DRAFTSMAN (ELECTRICAL). Must be technical school graduate with at least 3 years drafting room experience and capable of handling the electrical design work on steam or hydro electric stations and high or low tension substations. DRAFTSMAN (ELECTRICAL)—B. Must have had at least 2 years drafting room experience in underground power distribution and building illumination. DRAFTSMAN (MARINE MACHINERY)—C. Must have had experience in theoretical and practical engine, boiler and propeller design and construction of laying out and installing all types of piping systems and auxiliary machinery. Credit will be given for a knowledge of internal combustion and turbine machinery. Applicants should indicate the minimum salary which they would accept, bearing in mind that free furnished bachelor quarters are supplied on the Isthmus, and meals can be obtained at the Government restaurants at about 40c. each and upward. Z-878 A-B-C.

LUBRICATION ENGINEER for the Philippines: must be able to speak Spanish fluently and must be experienced as there is no time for instruction. Salary $3000 and traveling expenses. Location Philippines. Z-901.

POWER HOUSE DESIGNING DRAFTSMAN at the Muscle Shoals hydro-electric power development. Salary not stated. Location Alabama. Z-909.

ELECTRICAL ENGINEER for designing power plants, telephone systems, etc. Location New York City. Z-912.

DEVELOPMENT WORK of Tungsten products pertaining to manufacturing of filament for incandescent lamps. Recent graduate or undergraduate could qualify. Location Bloomfield, N. J. Z-919.

SALES ENGINEER who has had a commercial experience. Must have the commercial rather than the engineering viewpoint. A young man ambitious, enthusiastic, steady and stable, unquestionably loyal, a good letter writer, having a good conception of what is needed to write advertisements for engineering products. Location New York City. Z-932.

YOUNG MAN preferably just out of school to act as clerk, at steel plant. Prefer man with some electrical, technical education, who is looking for some good practical experience along the electrical lines in a steel plant. The work at present will consist of keeping office records, doing some test work, and probably some per month, and should offer an exceptional opportunity for advancement to the right man. Location Delaware. Z-934.

ENGINEER with broad experience in illumination field, should be posted on development of methods of illumination measurements and design of apparatus for such measurements, the direction of special illumination testing, the design of units, the selection of lamps for special work such as is encountered in various signal systems, development of home and farm lighting outfits. Location Northern New Jersey, near New York. Z-940.

MECHANICAL AND ELECTRICAL ENGINEER with several years experience to be the head of a power and machine shop department. Location Massachusetts. Z-941.

ASSISTANT EDITOR. Engineer familiar with gas engines and if possible some garage or automobile work. College graduate with one or two years experience preferred. Services not required until first or middle part of June. Excellent opportunity for advancement. Z-953.

ELECTRICAL DRAFTSMAN to act as designer and squad leader. Must be experienced in layout and design of generating stations and substations. Location New York City. Opportunity for advancement. Appointment must be made by letter stating salary expected and experience. Location New York City. Z-955.

SENIOR PROFESSOR OF MECHANICAL DRAWING (A) SENIOR PROFESSOR OF MECHANIC, desirable that he have practical and commercial experience. (C) ASSISTANT PROFESSOR IN ELECTRICAL ENGINEERING. Location South. Z-956.

INSTRUCTORS, 1000 men for army vocational schools. Mechanical and other subjects such as, auto repair, moving picture operation, machine shop practise, bookkeeping, etc. Civil Service entrance examinations. Location Army camps and posts. Z-961.

MECHANICAL DRAFTSMAN experience in smelting and metallurgical work desirable, or general experience in structural work and machine design will be considered. Knowledge of Spanish desirable but not essential. Z-977.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING. The man for this position must be qualified to teach the fundamentals of Direct and Alternating current theory, and to take charge of a class in Elementary Design. We would prefer a man who has had some experience in special electrical design such as Electrical Railways and Radio work. We would however emphasize the value of his teaching experience above his special work in application. Salary would be $2500. Location Ohio. Z-980.

INSTRUCTORS IN ELECTRICAL ENGINEERING. We shall need two men as instructors in Electrical Engineering. These men should be qualified to handle classes in Electrical Laboratory. They would be more valuable to us if they are able to take charge of class room work for Junior nonelectrical students. This position will pay from $1600 to $2000, depending on the experience of the man. Location Ohio. Z-981.

YOUNG CONSTRUCTION ENGINEER (A) with western mining and smelter experience if possible for work in Peru. SWITCHBOARD OPERATOR (B) must have experience in hydro-electric work. SHIFT BOSS (C) experienced in hard rock ground and square set timber. Must be used to handling Spanish labor. Unmarried men preferred for all of these positions, or married men who are willing to go without family and send for them later. Spanish essential. Only engineers used to working in high altitude will be accepted. Transportation and lodging furnished. Board $25 per month. Z-994-A-C-B.

ELECTRICAL ENGINEER for laboratory testing of raw material to finished product. Will also be in charge of about 20 men. Location Yonkers, New York. Z-998.

ELECTRICAL ENGINEER for efficiency tests and for general electrical testing on all kinds of motors and electrically heated ovens. Recent graduates considered. Location Tarrytown, New York. Z-1007.

INSTRUCTOR to teach elementary mathematics and mechanical drawing in Apprenticeship School. Candidates should have had some technical training and shop experience and should understand the handling of young men. This position offers excellent opportunities for advancement in the Works through one of its many departments. Location Connecticut. Z-1012.

MAN to take up work in the laboratory of a large Electrical Manufacturing and Sterilizer Equipment Company. This work will have to do with electrical and chemical experiments and it would seem that a young man probably a college graduate in Electrical Engineering, would be most suitable. Location New Jersey. Z-1014.

MECHANICAL ENGINEER to take charge of machinery for the

treatment of Asbestos fiber. Must be thoroughly proficient mechanical engineer, with good knowledge of electrical power. Must also be good executive. Location New York City. Z-1015.

ASSISTANT SUPERINTENDENT OF ELECTRICAL DEPARTMENT. Technical graduate with some experience in electrical construction work. Duties would consist of drafting office work and outside construction supervision. Must also be able to assist in systematizing department employing about 30 men. Z-1079.

ELECTRICAL ENGINEER (A) with 3 or more years teaching experience, desiring to make change to electrical machine design work wanted, to take up interesting line of alternating current development. Splendid opportunity for man of ability and energy to make permanent connection. ENGINEER (B) with technical training, experienced in design of alternating current motors to take up development of adjustable and varying speed alternating current equipment. Permanent position with good opportunities for growth. TECHNICALLY TRAINED ENGINEER (C) with railway operating experience, desiring to make change to design work, wanted for development work connected with railway electrification. Permanent position for man of ability. Z-1093 A-B-C.

MEN AVAILABLE

ELECTRICAL ENGINEERING GRADUATE: energetic and ambitious desires position in engineering department of firm where he is given an opportunity to advance according to ability shown. Power plant and substation work preferred. Have had two years drafting experience. Location desired Chicago. E-2142.

ELECTRICAL ENGINEER: University graduate, twelve years varied experience, electrical, mechanical, steam and hydraulic, with mining, industrial and hydro-electric companies in field and office; design, construction, maintenance, operation; good organizer. Age 34, salary $300. Available about June 1st. E-2143.

ELECTRICAL ENGINEER: desires position in consulting or industrial line. Over five years experience with leading electrical manufacturer. Shop testing, railway equipment installation and industrial equipment installation comprise part of practical experience. Over three years railway application engineer, handling substations distribution systems, equipment applications, traffic studies and operating cost analyses. E-2144.

ELECTRICAL ENGINEER: A. B. degree Princeton; G. E. test course; ten years in steam railroad electrification; Six years originating and developing electric apparatus with two manufacturing concerns, including considerable number of highly successful devices. Location in vicinity of New York preferred. Salary $6600 to $7500. E-2145.

ELECTRICAL ENGINEER: university graduate, age 38, married; fourteen years' experience—drafting, appraising, estimating, designing, layout and installation of large railway distribution system, eight years in responsible charge desires to locate in the west; salary, $5,000. E-2146.

ELECTRICAL GRADUATE: Cooper Union 1918, B.S. degree, Assoc. A. I. E. E., wishes position in New York City in engineering department of progressive concern. Training, experience, and references of the best. American citizen by birth. Salary $50. E-2147.

ENGINEER: as factory or sales executive, technical education, broad experience, initiative, and ability to get results. Seven years with General Electric, designing and sales. At present Sales Manager, heavy machinery for New York and New England. Age 31, salary required $6000. E-2148.

EXECUTIVE: with civil and electrical engineering experience in railroad location construction, Hydro-electric and industrial design, construction and operation. A good organizer with a large following, 38 years old. E-2149.

FACTORY EXECUTIVE: Graduate electrical engineer large experience in mechanical and electrical engineering and factory management. Manager of plants employing 200 to 400. Familiar with modern machine shop practise and methods and equipment for maximum quantity production. Salary $5,000. Available 30 days. Location Northern Ohio. E-2150.

ELECTRICAL SUPERINTENDENT: Age 33, five years practical experience covering shop repair, wiring, testing and trouble shooting, 10 years in charge of installation, maintenance operation, layouts and technical work in connection with the above on cranes, power, lighting and controlling equipment in the iron and steel industry. Fully qualified by experience and training to take charge of both the electrical and mechanical equipment. Address L. F, 34 Brown Ave., Akron, Ohio. E-2151.

INDUSTRIAL ELECTRICAL ENGINEER: Available April 20th. Technical graduate, 10 years experience, generating and substations and distribution systems; designs specifications, schedules, construction, large and small systems. Considerable study given factory power problems and operating features. West or Middle West location preferred. E-2152.

ASSISTANT PLANT OR WORKS ENGINEER: Capable, energetic electrical-mechanical engineer invites correspondence with progressive manufacturing concern desiring the services of an assistant plant or works engineer. Four years experience including G. E. Test, industrial application of power, light, and gas; and the application of A. C. and D. C. power to coal mining. Single, technical graduate, Assoc. A. I. E. E. Salary $2800. E-2153.

ASSISTANT CHIEF ELECTRICIAN: Technical education 9 years experience testing, construction and maintenance of generating stations, substation, underground systems, oxygen Hydrogen Plant, Repair shop and industrial plants. Present salary $2600 Western States. E-2154.

CHIEF ELECTRICIAN: two years technical training, fifteen years practical experience in mining and industrial plants. Age 39 years; salary eighteen hundred per year. E-2155.

GRADUATE ELECTRICAL ENGINEER: Seven years with large power and industrial companies. Experienced in construction and operation of power plants and in operation of transmission lines and electrical equipment. Now employed but available for service on short notice. Salary $250 to $300. E-2156.

DEVELOPMENT OR RESEARCH ENGINEER: Ten years experience Inspection Electrical Testing and special Investigations. Work requiring knowledge of Advanced Mathematics preferred. Location N. Y. C. or vicinity. E-2157.

ELECTRICAL ENGINEER: A.B. and E.E.; seven years experience with a large manufacturer of telephone apparatus; 8 years head of department of electrical engineering in a state university; has done much work of the Dean; desires teaching or commercial position. Minimum salary $4000. Salary scale too low at present location. E-2158.

ELECTRICAL ENGINEER: age 39, with the General Electric Company in the Testing Department two years, in their turbine power station two years, have been with present employers twelve years superintending operation and construction in twelve thousand kilowatt steam turbine driven power station. Have had experience in burning low grade fuels and handling men. Salary $5000.00. E-2159.

ELECTRICAL ENGINEER: age 31, married, 10 years experience construction and installation, sub-station, transmission, distribution and power equipment; also land survey. Can furnish references as to character and ability. No preference as to location. Minimum salary $3000. E-2160.

ELECTRICAL ENGINEER: Assistant professor of Electrical Engineering will be available from June 1st to Sept. 10th. Thoroughly experienced in electrical testing and inside electrical construction work. E-2161.

ELECTRICAL ENGINEER: at present Assistant Superintendent Lighting and Power Public Service Company in city sixty thousand. Technical Graduate, nine years experience General Electric Company and Central Station as Engineer and Executive. Age twenty-nine years, married. Desires change. E-2162.

ELECTRICAL ENGINEER: College graduate 1913. Four years with large traction company and three years with construction company. Drafting, designing, and checking experience on power station and industrial layouts. Field experience. Quick and accurate at engineering computations. Desires connection with engineering office of recognized standing. New England preferred. E-2163.

ELECTRICAL ENGINEER: Cornell M.E. 1918 desires position with industrial concern, manufacturer of electrical apparatus or electrical contractor. Some testing experience; thoroughly familiar with electrical contracting, layouts of lighting systems and power installations. At present employed with large street railway company. Will go anywhere. E-2164.

ELECTRICAL ENGINEER: Cornell graduate, 1918, age 23, single, Associate, desires position in electric furnace field. Six months general testing experience. Lt. S. C. radio for past 18 months engaged in experimental and development work on electric furnaces together with some construction and operation. Salary depending on location. E-2165.

ELECTRICAL ENGINEER: experienced in handling men, general large plant engineering, designing plant installations of motors, generators, substations, over head and underground transmission systems, repairs and maintenance, also

operation of same. Experienced in purchasing and office management, drafting room work desires position as plant engineer or engineer with a firm of consulting engineers. Married, 33 years. Technical training. Salary $7000.00. E-2166.

ELECTRICAL ENGINEER: technical graduate; age 31, ten years experience in design, construction and supervision of maintenance and operation of power plants for industrial plants and public service corporations; Proficient in making estimates, analysis and reports; desires position as electrical engineer for industrial plant or manager for light and power company. E-2167.

ELECTRICAL ENGINEER: technical graduate. Ten years experience in charge of electric construction and operation including power plant and substation work, switchboard, under-transformers and synchronous motors. Best of references. Location, Pacific Coast. Minimum salary $3600. E-2168.

ELECTRICAL ENGINEER: technical graduate seven years experience along construction, maintenance and distribution of power for public utility and construction engineers. E-2169.

ELECTRICAL ENGINEERS: with wide experience in Central Station field and in Industrial power production and application; skilled in preparation of plans, specifications, selection of equipment, organization and control of operating forces; have handled all classes of equipment from water supply to power application. Now open for engagement. E-2170.

ELECTRICAL ENGINEERING INSTRUCTOR: in a leading eastern university,—with past graduate training in Physics, varied engineering and research experience, will be available July 1st for summer or permanent work. Desire engineering or industrial research. Prefer western location for permanent work. Married, age 28. E-2171.

ELECTRICAL AND MECHANICAL ENGINEER: Cornell graduate 1904—Employed as assistant consulting engineer. Experience in all mechanical and electrical features of power and industrial plant design, operation, and maintenance. Minimum salary $5000. Will consider association with Civil and Chemical Engineer for consulting practise in complete design of manufacturing plants and processes. E-2172.

GRADUATE ELECTRICAL ENGINEER: Age 27, married. At present am Sales Engineer for Electric Control Manufacturer. Before leaving Home Office was Asst. Chief Engineer. Desires position with Electric Crane Manufacturer. Salary $225. a month. Location Middle-West. E-2173.

GRADUATE ELECTRICAL ENGINEER: at present employed by large electrical manufacturing company, 1½ years teaching in large university; 2 years mining and general engineering work; 1½ years G. E. Test and engineering department. Thoroughly familiar with mining, power plant and substation work. Available on short notice. E-2174.

GRADUATE ELECTRICAL ENGINEER: possessing unusual qualifications. Four years business, office and sales experience. Six years engineering experience in responsible positions with several large public utility corporations. Especially fitted to handle an executive position of business nature requiring engineering experience and technical knowledge. Now holds an executive engineering position. E-2175.

HYDRAULIC AND ELECTRICAL ENGINEER: University graduate in 1913, seeks a change in position. At present teaching in an Eastern University of first rank, in responsible charge of hydraulic work. Small consulting practise. Work desired is on hydraulic power developments, investigation and design, where executive ability is necessary. Minimum salary $3600. E-2176.

PRACTICAL ELECTRICAL MAN: on D. C. Shop Practise, age 39 yrs., single, about 18 yrs., practical shop experience, graduate of New York Electrical School, at present Chief Electrician in Steel Mill. Service available on two weeks notice. State particulars of position in first answer. E-2177.

PROFESSOR: in charge of Electrical Engineering Department in eastern University desires to make a change this year. Eighteen years teaching and practical engineering experience. Desires either professorship or practical work. Present salary too low. E-2178.

SALES ENGINEER: With Executive experience desires opening as Sales Manager or an Agency with a Company of good standing. Graduate E.E. experienced in test, design, operation and sales of electrical machinery as well as manufacture and operation of storage batteries. Good appearance and forceful personality. Acquaintances in New York and vicinity. E-2179.

TECHNICAL GRADUATE: age 23, five years experience, shop, test engineering, service, sales engineering with large electrical machinery manufacturer desires position, vicinity New York City (not selling) with good future. Minimum salary $2300.00. E-2180.

TECHNICAL GRADUATE: University of Kansas, age 27, energetic, ambitious, four years Philippines and Orient, understanding labor conditions, two years trade school principal, one year superintendent maintenance electric railway, two years captain Coast Artillery, desires position with future. Entrance salary accepted dependent on future possibilities. E-2181.

TECHNICAL GRADUATE: Age 34, married, with eighteen years practical experience, on power and substation operation and maintenance on three large systems. Desires responsible position with utility or industrial company. At present in charge of lighting railway and power substations. Can furnish best of references. Have good reasons for change. E-2182.

TECHNICAL GRADUATE: Three years practical and eight years teaching experience along electrical and mechanical lines. Desires position as supervisor or teacher of electrical subjects. Will consider a commercial position. Age 35, married. E-2183.

TELEPHONE ENGINEER: Graduate Cornell University. Twelve years experience in preparing plans and estimates for inside and outside plant, and in valuation of Telephone and Telegraph Plants. Now engaged in valuation of property for rate case. Minimum salary $3600. E-2184.

YOUNG MAN: Age 28; single; associate; some technical training and five years experience on the operation and maintenance of electrical machinery. Recently from the Naval Service in which held an executive position with an excellent record. Desires position preferably maintenance. Minimum salary $1800. Location New York. E-2185.

TECHNICAL EXECUTIVE OR TECHNICAL ASSISTANT TO EXECUTIVE: Twelve years Public Utility operation, construction and management. Four years executive in charge of power plant and industrial design and construction. Can organize and handle others. Plenty of tact and analytical ability. Available June 1st. E-2186.

DESIGNING ENGINEER: Mechanical, electrical, steel and concrete design of Power Plants and industrial buildings. Efficiency problems and commercial analysis; 10 years experience; whole or part time; located in N. Y. City. E-2187.

GRADUATE ELECTRICAL ENGINEER: middle western university, 1918; age 31; one year post graduate course; one year engineer officer, U. S. Navy; associate, A. I. E. E. Desires position with power or manufacturing company. Available in June. E-2188.

ELECTRICAL ENGINEER: Post-graduate of engineering school. 33 years old, married. Speaks French. Technical experience in electric machinery testing and installation and in storage battery work. Now Assistant Professor of Electrical Engineering in state university. Wishes to engage in commercial work. $300 per month, minimum. E-2189.

TECHNICAL ELECTRICAL MAN: age 28, married, has had 5 years of varied electrical teaching experience. Desires to quit teaching and locate in the southwest. References on request. E-2190.

ELECTRICAL ENGINEER: technical graduate, age 43. Three years in Westinghouse works and testing departments. Eighteen years commercial and technical experience involving negotiations with public utilities and designing of transmission lines, substations and power plants. Salary $6000. Available on reasonable notice. E-2191.

FOREMAN & CHIEF ELECTRICIAN with broad practical engineering experience in industrial and power plants in charge of construction, installation and maintenance. Can maintain essential efficiency in organization. Western states preferred. Fourteen years in business. 31 years of age. Married. Minimum salary to start $2700. E-2192.

STEAM & ELECTRICAL ENGINEER; Assistant to Superintendent or chief engineer in charge of power plants, industrial works or central station. Competent to take charge of operation, efficiency and maintenance of boilers, pumps, turbines, and electrical equipment. Position with good prospects of advancement desired. Salary $2000. E-2193.

MAINTENANCE ENGINEER, age 37, with 20 years, both technical and practical experience in the construction, operation, upkeep and repair of electrical and mechanical equipment of industrial plants, buildings, and railways, including power generation. Married; Associated A. I. E. E. Location immaterial. Available immediately. Salary to commensurate with responsibilities and location. E-2194.

GRADUATE ELECTRICAL ENGINEER, age 32; experienced in installation and maintenance of switchboards and electrical equipment both A. C. & D. C. in steel mills and factories. One years testing experience on A. C. & D. C. motors; three years mechanical design. Minimum salary $4000. Reasonable notice. E-2195.

GRADUATE ELECTRICAL ENGINEER, age 26; single; with two

years experience in telephone engineering, 6 months industrial plant maintenance, and 5 months in the design and layout of power plants and substations, desires change. Location anywhere; East or Middle West preferred. Available on short notice. E-2196.

ELECTRICAL ENGINEER with special training in Mathematics desires position, high tension power work preferred. Graduate A. B. and also E. E. at M. I. T. Fifteen months experience on large power system. Single. Will locate anywhere. Salary about $200. E-2197.

TECHNICAL GRADUATE, 35 years of age, married, executive ability, 10 years experience with operation of electrical and mechanical machinery and equipment, desires a change to a small growing manufacturing concern where the chances of expansion are greater. E-2198.

OBITUARY

JOSEPH T. TOMLINSON, late assistant chief electrician with Spang, Chalfant & Co., Etna, Pa., died March 11, 1920. Mr. Tomlinson was born April 19, 1887, and had been with Spang, Chalfant & Co. since 1905, becoming chief electrician in 1913. He joined the Institute as Associate in 1917.

KATHERINE AUGUSTA, wife of RALPH W. POPE, Honorary Secretary of the Institute, died at her home, 570 Cherry Street Elizabeth, N. J., on March 18 from the effects of cerebral hemorrhage, after an illness of one month. Her remains were taken to Great Barrington, Mass., March 22 for interment in Mahaiwe Cemetery. Mrs. Pope was personally known to many of the Institute members through her presence at several conventions.

JOHN A. BRASHEAR, past president of the American Society of Mechanical Engineers, and chairman of the John A. Brashear Co., Pittsburgh, died April 8, 1920, at his home in Pittsburgh. Born in Brownsville, Pa., in 1840, Mr. Brashear received his education in the public schools there. He early took up a trade as machinist, but following his hobby, astronomy, to which he had devoted much of his spare time, he turned his attention to the construction of astronomical and physical instruments in 1870, and since 1880 was actively engaged in their manufacture. He received honors from many of the leading engineering institutions for his scientific work, and several university degrees. Among P ttsburghers he was widely known as "Uncle John." At the Midwinter Convention of the A. I. E. E. in 1919 he delivered an address before the Institute on "An Evening with the New Astronomy."

JOHN D. IHLDER died on April 3, 1920. Mr. Ihlder was born in Germany in 1848, and had his early school training there, but on coming to America received his college education at Cornell University, from which he was graduated in Electrical Engineering in 1887. Practically all of his work since then has been connected with the Otis Elevator Company, for which he was chief electrical engineer for a number of years, later becoming a member of the Board of Consulting Engineers. The greater part of the electric elevators of the company were built under his patents. Mr. Ihlder was first elected to the Institute as Associate in 1888, becoming a Member in 1903 and a Fellow in 1912. He left New York in 1919 for Cincinnati, Ohio.

THEODORE N. VAIL, a Charter Member of the Institute, and Chairman of the Board of Directors of the American Telephone and Telegraph Company, died at Johns Hopkins Hospital on April 16, 1920. Mr. Vail was born in Carroll County, Ohio, July 16, 1845, his parents soon returning to Morristown, N. J., where he was educated. In later years he received the degree of LL. D. from Dartmouth, Middlebury, Princeton, and Harvard, and the degree of D. Sc. from the University of Vermont. He realy became interested in telegraphy, and abandoned the study of medicine to take up a career as telegraph operator. In 1868 he received an appointment in the railway mail service, and his suggestions for its improvement led to his transfer to Washington in 1875, as general superintendent of the service. Here he met Alexander Graham Bell, and had such faith in his invention of the Telephone that he resigned his position to become head of the first American Bell Telephone Company. When the American Telephone and Telegraph Company was organized in 1885 he became its President, devoting his energies to the extended use of the telephone, and to its development, seizing upon every invention that tended to improve it. From 1887 to 1893 Mr. Vail traveled for his health, and in 1893 retired to his farm in Vermont, but several years later went to Argentina, where he introduced the American system of electric street railways in Buenos Ayres and installed a telephone system in the principal cities of the country, returning to the U. S. in 1904. In 1907 he returned to active work, becoming again the head of the American Telephone and Telegraph Company, with which he remained first as President and later as Chairman of the Board of Directors until his death. During the period of war when the telegraph and telephone properties of the country were taken over by the Government, Mr. Vail was appointed general manager of all telegraph and telephone lines. He always declined to enter public life; although his firm belief was that close cooperation between education, science, and industry were for the best development of the country as a nation. He was a member of many clubs and scientific societies.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities, is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Harvey G. Brooke, 6543 Regent, Philadelphia, Pa.
2.—Arthur J. Hall, 634 East End Avenue, Pittsburgh, Pa.
3.—J. C. Lawler, 1817 Glenarm Street, Denver, Colo.
4.—Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.
5.—Harry E. Stone, 313 Trenton Avenue, Wilkinsburg, Pa.
6.—Lieut. W. J. Strieby, 34 Simpson Road, Ardmore, Pa.
7.—Charles P. Wood, Metuchen, N. J.

INSTITUTE YEAR BOOK

The A. I. E. E. 1920 Year Book is available to members, without charge, upon application to the Secretary, 33 West Thirty-ninth Street, New York.

The book contains an alphabetical and geographical catalogue of the membership revised to January 1, 1920; also the constitution, by-laws, lists of officers and committees, and considerable additional information relating to the activities of the Institute.

SUPER-POWER SYSTEM

At a session of the Institute held during the Midwinter Convention, in February 1920, Mr. William S. Murray presented a paper, published in the March JOURNAL, "Economical Supply of Electric Power;" and during the discussion on this paper a motion was offered and adopted, recommending to the Board of Directors of the Institute that a committee be appointed to carry on the movement as outlined by Mr. Murray.

This recommendation was approved at the meeting of the Board of Directors of the Institute held in Pittsburgh, March 12; and President Townley was authorized to appoint such a committee. In accordance with this action of the Board, President Townley has appointed a Special Committee on Super-Power System, consisting of Messrs. W. S. Murray (Chairman), H. V. Bozell, H. W. Buck, George Gibbs, J. W. Lieb, Malcolm MacLaren, William McClellan, C. S. Ruffner, D. B. Rushmore, Charles F. Scott, Percy Thomas.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (MARCH 1-31 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AMERICAN CIVIL ENGINEERS' HANDBOOK.

Editor-in-Chief, Mansfield Merriman. Fourth edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 1955 pp., tables, 7 x 4 in., flexible cloth, $6.00.

The fourth edition of this well-known reference work follows the plan of the previous editions and is the achievement of a board of eighteen associate editors, under the direction of Prof. Merriman. The volume has been thoroughly revised, a collection of mathematical tables included and new sections added on electric railways, irrigation and drainage. Nearly four hundred pages have been added to the work. Because of the comprehensiveness of the book, it has been entitled a "Handbook" instead of, as formerly, a "Pocket Book."

AMERICAN MACHINISTS' HANDBOOK.

A Reference Book of Machine Shop and Drawing Room Data, Methods and Definitions. By Fred H. Colvin and Frank A. Stanley. Third edition, thoroughly revised and enlarged. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 758 pp., illus., diagrams, tables, 7 x 4 in., flexible cloth, $4.00.

This pocketbook has been prepared to present in convenient form such data as will be of value to practical men in the various branches of machine work. The present edition has been thoroughly revised. Seventy-seven pages have been added and much other new material included by the elimination of less important matter from the previous edition.

DAVISON'S SILK TRADE.

A Directory of the Silk Manufacturers of the United States and Canada including Silk Dyers, Finishers and Printers; Manufacturers' Agents; City offices and Salesrooms of Silk Mills; Dealers in Raw, Thrown, Spun and Artificial Silk; Waste; Cotton, Tinsel and Worsted Yarns. 25th annual edition, 1920. N. Y., Davison Publishing Co., 782 pp., 7 x 5 in., flexible cloth, pocket edition, $3.00.

The scope of this directory is fully shown by the title. The directory of manufacturers appears in three sections, classified alphabetically, geographically and by the kind of goods made. The other sections are arranged geographically or alphabetically, as seems more expedient. The volume is of pocket size and provided with a marginal index.

ARMATURE WINDING AND MOTOR REPAIR.

By Daniel H. Braymer. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 515 pp., illus., tables, 8 x 6 in., cloth, $3.00.

This book does not discuss the subject from the point of view of theory or design, but is a compilation of practical methods used by repair men and armature winders. The methods selected are those which represent the best practise in repair shops of average size and are given in detail.

DESIGN AND CONSTRUCTION OF HEAT ENGINES.

By Wm. E. Ninde. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 704 pp., illus., diagrams, tables, 9 x 6 in., cloth, $6.00.

CONTENTS: The Heat Engine; Thermodynamics; Friction and Lubrication; Power and Thrust; Mechanics; Machine Design.

The object of this book is to supply in one volume the material most essential to the well-equipped, independent designer of heat engines, and to give this material in the form most convenient for use in class room and practical work by a separate treatment of the different phases of the subject. The book is the outgrowth of twenty years experience, and a study of the literature, drawings and practical data. The volume is confined to the steam engine, steam turbine and internal combustion engine.

THE DESIGN OF SCREW PROPELLERS.

With Special Reference to the their Adaption for Aircraft. By Henry C. Watts. Lond. and N. Y., Longmans, Green and Co., 1920. 340 pp., illus., charts, diagrams, plate, tables, 9 x 6 in., cloth, $8.

During the war, the author was in charge of technical work in connection with propellers for aircraft at the Admiralty and Air Ministry of Great Britain, and many of the propellers used were designed by him or under his supervision. This volume records the results of his experience. It is intended as a guide to practical design and gives slight attention to mathematical theory of the behavior of screw propellers. A chapter on the design of windmills is included.

ELECTRIC LIGHTING.

By Olin Jerome Ferguson. First edition, N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 243 pp., illus., diagrams, tables, 9 x 6 in., cloth, $2.50.

While a number of excellent books exist which cover certain portions of the field included in the title of this volume, the author believes that there is need for a work giving a well-balanced presentation of fundamentals, with principles and practise explained throughout. This need he has tried to meet with a textbook of moderate size.

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES.

With Application to Radiotelegraphy and Incidental Application to Telephony and Optics. By George W. Pierce. First edition. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 517 pp., diagrams, tables, 9 x 6 in., cloth, $5.00.

This book is designed to present a mathematical treatment of some of the fundamentals of the theory of electric oscillations

and electric waves. In the selection of material, the writer has given first consideration to that which is particularly applicable to radiotelegraphy, yet he hopes that as the electromagnetic theory involved in radiotelegraphy is also fundamental to optics, telephony and power transmission, his work will also be useful to students of these subjects.

FLOW AND MEASUREMENT OF AIR AND GASES.

By Alec B. Eason. Lond., Charles Griffin & Co., Ltd.; Phila., J. B. Lippincott Co., 1919. 252 pp., illus., diagrams, tables, 9 x 6 in., cloth, 25 shillings.

The engineering problems investigated in this book arise in connection with pneumatic tubes and compressed air, gas lighting and ventilating systems. The author has investigated, by study of the literature and by experiment, the friction of gases and the coefficient of friction in pipes, the question of suitable meters for gas and air, and the working of pneumatic tubes; and has attempted to coordinate the results of the various tests and formulas, so that the reason for variations may be appreciated. Full references to the sources of information are given.

GRAPHIC PRODUCTION CONTROL.

By C. E. Knoeppel, assisted by Various Members of the Author's Firm and Staff. N. Y., The Engineering Magazine Co., 1920. 477 pp., illus., diagrams, charts, 9 x 6 in., cloth, $6.00.

This treatise on the use of graphic charts in shop control is intended to provide a complete description of the proper methods of making graphic charts and of applying them to industrial problems. The general principles of graphic control, the preliminaries of its installation, the practical operation of the system, etc., are discussed in detail.

HENDRICKS' COMMERICAL REGISTER OF THE UNITED STATES FOR BUYERS AND SELLERS.

28th Annual edition, 1919–20. N. Y., S. E. Hendricks Co., Inc. 2541 pp., 10 x 8 in., cloth, $12.50.

This new edition, like its predecessors, is devoted to the electrical, engineering, hardware, iron, mechanical, mill, mining, architectural, quarrying, chemical, railroad, steel, contracting and kindred trades. The firms included are listed alphabetically and by products. A subject index and an index of trade names are also included.

INTRODUCTION TO GENERAL CHEMISTRY.

By Herbert N. McCoy and Ethel M. Terry. Second edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 648 pp., illus., 9 x 6 in., cloth, $3.00.

This textbook is intended as an introduction to general chemistry for use by college freshmen and is based on the course in the University of Chicago. The aim has been to present a continuous, connected story in teachable form, without unnecessarily extensive descriptive and numerical data.

In this edition misprints have been corrected and a chapter on metallurgy added.

THE IRON HUNTER.

By Chase S. Osborn. N. Y., The Macmillan Co., 1919. 316 pp., plates, portraits, 8 x 5 in., cloth, $2.00.

Ex-Governor Osborn of Michigan has been closely associated with the development of the iron ores of the Northwest and of Canada from the early "eighties" to the present. It has been his hobby to visit all the commercial iron fields of the world. His autobiography is an interesting, unconventional account of his life as a journalist, prospector and statesman, full of information about men and affairs during the early mining days in Wisconsin and Michigan.

MANUAL OF CYANIDATION.

By E. M. Hamilton. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 277 pp., illus., tables, 7 x 5 in., flexible cloth, $3.00.

The aim of this book is to provide in a handy sized volume a compendium of all the ascertainable facts concerned with the cyanide process that may have a practical bearing on testing an ore, planning the flowsheet and operating the plant when erected. Purely theoretical questions have been left in the background.

MENSURATION FOR MARINE AND MECHANICAL ENGINEERS.

(Second and First Class Board of Trade Examinations). By John W. Angles. Lond. & N. Y., Longmans, Green and Co., 1919. 162 pp., illus., diagrams, 7 x 5 in., cloth, $1.75.

This textbook is intended to enable students to pass the examinations of the Board of Trade (Great Britain) for licenses as marine engineers, but will be useful, the author hopes, to engineering students in other lines. A feature is made of fully solved examples, illustrating the practical applications of the theoretical principles involved in the text.

METALLOGRAPHY. Part I. Principles of Metallography.

By Samuel L. Hoyt. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 256 pp., illus., diagrams, tables, 9 x 6 in., cloth, $3.00.

This volume, the first of a series of a series of three based on the author's lectures at the University of Minnesota, deals with general principles and with some of the more important methods used in general investigations in the metallographic laboratory. Future volumes will discuss the metallography of the metals and alloys and the applications of metallography to the metallurgical and engineering industries.

MICROSCOPIC EXAMINATION OF THE ORE MINERALS.

By W. Myron Davy and C. Mason Farnham. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 154 pp., illus., tables, 9 x 6 in., cloth, $2.50.

The authors present a table for determining the identity of ore minerals by means of the reflecting microscope and microchemical tests, for the use of mineralogists, geologists and engineers. In addition to the table, instruction in polishing and examining specimens and in photomicrography is given, as well as a collection of supplementary tests.

MINERAL RESOURCES OF ARMENIA AND ANATOLIA.

By Hagop A. Karajian. First edition. N. Y., Armen Technical Book Co., 1920. 211 pp., illus., maps, 9 x 6 in., cloth, $3.

A summary of our knowledge of the mineral resources and the present state of the mining industry in Armenia and Anatolia, accompanied by a survey of the geology of the region. A number of sketch maps and a bibliography are included.

MOTOR VEHICLE ENGINEERING.

Engines (For Automobiles, Trucks and Tractors). By Ethelbert Favary. Second edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 333 pp., illus., plates, tables, 9 x 6 in., cloth, $3.50.

The author states that many chapters of this edition have been entirely rewritten, that the practical data have been brought up to date and that the work has been generally revised. The book treats of automobile engines and is intended to give a concise, simple statement of the everyday information needed by automotive engineers.

L'OR. Prospection—Gisement—Extraction.

By Georges P. Proust. Paris, Gauthier-Villars et Cie, 1920. 319 pp., illus., 9 x 6 in., paper, 10 francs.

This work by a French mining engineer is a summary account of the mining and metallurgy of gold. After an introductory chapter on mineralogy, the author treats of prospecting and testing, exploitation, preparatory treatment, cyaniding, mining costs and alluvial mining. A chapter of advice on hygiene and diet for residents in tropical lands is included, and also a mineralogical lexicon. The book is evidently intended for engineers engaged in the development of new mines.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH.

By C. E. Kenneth Mees. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 175 pp., 8 x 6 in., cloth, $2.00.

CONTENTS: Types of Research Laboratories; Co-operative Laboratories; Position of the Research Laboratory in an industrial Organization; Internal Organization of Industrial Research Laboratories; Staff of a Research Laboratory; Building and Equipment of the Laboratory; Direction of the Work; Design of a Research Laboratory for a Specific Industry.

This volume is a contribution to the current discussion of the relation of scientific research to industry. The author is concerned with a study of the best methods of organizing research work for industrial purposes and of the conditions under which such work should be conducted, and has made an effort to give definite suggestions upon these points. The book is intended for those who plan to undertake research work rather than as an exposition of its theoretical advantages.

Statistics in Business.

Their Analysis, Charting and Use. By Horace Secrist. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 137 pp., illus., diagrams, maps, tables, 8 x 6 in., cloth, $1.75.

This volume has been prepared to serve as a handbook for executives in the application of business statistics to problems which arise. It aims to present briefly and concretely the reasons why statistics should be used in business analysis and to illustrate how and with what effect they may be applied to the solution of business problems. The discussion is of a practical nature. Especial attention is given to the use of charts and graphs. Examples of good and bad usage are given.

Thomas' Register of American Manufacturers and First Hands in All Lines. 11th edition, 1920.

N. Y., Thomas Publishing Co., 1920. 12 x 9 in., cloth, $15.00.

Contents: Finding List and Index; Lists of Manufacturers Classified according to Business; Manufacturers of the U. S. arranged alphabetically; Leading Trade Names, Brands, etc.; Banks, Boards of Trade and other Commercial Organizations, Leading Trade Papers; Manufacturers' Representatives; Export and Import Houses; Steamship Lines and Forwarding Agents, Banks, etc.; Overseas Importers, Merchants, etc.

The eleventh edition of this widely known directory has been revised and enlarged to the size of 4500 pages. It covers manufacturers and dealers in all classes of materials, and contains a classified list of manufacturers with indications of their approximate ratings, an alphabetical list of the more important firm names, and a list of brand or trade names of manufactured articles.

White-Lead—Its Use in Paint.

By Alvah Horton Sabin. First edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 133 pp., tables, 8 x 5 in., cloth, $1.25.

In his small work Dr. Sabin has provided a brief, non-tehnical account of the subject for the instruction and guidance of those whose need and use of white-lead prompts them to seek knowlledge about it of a simple but reliable sort. The various methods of making white-lead are given together with the properties of the usual substitutes, methods of mixing paid for different purposes, etc.

Notes on Magnetism.

For the Use of Students of Electrical Engineering. By C. G. Lamb. Cambridge, England, University Press, 1919. 94 pp., 55 illus., 9 x 5 in., paper. (Gift of G. P. Putnam's Sons).

The author presents an outline of those essential parts of magnetic theory which a student of electrical engineering requires in order to read ordinary technical textbooks with intelligence. The book is based on the course at Cambridge University.

CONTROLLERS FOR ELECTRIC MOTORS

By H. D. James. D. Van Nostrand & Co. 1919.

The use of the electric motor has become so wide-spread and the methods of its application and control so numerous that at present none but a specialist is competent to make a decision from his own experience as to the most suitable motor and most appropriate method of control for the manifold applications. On the other hand these applications are so common that most practising engineers must frequently make recommendations of this character incidental to other engineering work.

The book "Controllers for Electric Motors" is a compilation of descriptions of the many ways in which motors are used in industrial work and of accepted methods of control for each process by a specialist who is recognized in the professional world as an authority on this subject. The list of applications discussed in the book is so long that only the most interesting can be mentioned here. Many of the discussions of the underlying engineering features have been given by the same author in the Transactions of the A. I. E. E.

One of the most interesting and valuable sections is that in which the author attacks the common fallacy of basing the determination of the requisite number of steps of a starting box on considerations of the resistance of the armature circuit alone. By means of a scientific analysis, illustrated by oscillograms the author points out that due to the fact that a measurable period of time is required for the field of a d-c. motor to build up, and since during this period the torque cannot be sufficient to cause a dangerous mechanical shock to the motor or gear, it is good engineering to take advantage of this feature to reduce the number of steps (and cost) of a starting rheostat.

The relative advantages of d-c. and a-c. motors for various applications are discussed very thoroughly and impartially and a good reason is given for every definite recommendation.

The use of auxiliary fly-wheel motor-generator sets, both with d-c. and a-c. motors is explained and the economic justification stated. However the latest type of speed control of large induction motors by means of a polyphase commutator motor is not described.

Many recently developed types of relays and magnetic switches are described and the possibility of developing the protective and automatic features of a control to an unnecessary complexity is clearly brought out with citations of cases where certain apparently highly desirable devices have been abandoned after some trial for the purpose of getting greater simplicity and ease of repair.

The success of the electric motor in supplanting the hydraulic drive for elevators is noticeable by the number of methods in which the motor has been adapted in commercial practise both for passenger and freight service. The saving in space required for the driving machinery is a very important factor in these days of high building costs. It would be almost impossible to construct a hydraulic elevator for a 40-story building whereas the adaptation and control of the electric motor has been worked out with interesting ingenuity.

Electric Drive in Steel Mills is a subject which hardly comes into the activities of the average general engineer because it is so involved as to be a specialty in itself, yet all engineers are interested in knowing the wonderfully clever things that have been accomplished in this line.

The Mining Industry has been one of the last and most difficult fields for the electric motor to enter and capture but it is clearly evident that the electrical engineer interested in this specialty has been very industrious and has produced a large number of ingenious devices which do very important work for the mining engineer. With the continual increase in the price of coal the time will soon arrive, if it has not already, when the mining plant cannot afford to generate its own power but will be forced by economic pressure to buy energy from the large electric power companies which by a peculiarity of nature usually find abundant water power in the vicinity of a mining country. When the mining engineer has to buy his energy in the form of electric current instead of coal he will fully appreciate the advantage of using it in the electric motor and then it may be fairly said that the electric motor has conquered all industrial fields. W. I. S.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Baltimore.—February 20, 1920, Engineers Club. Speaker: Mr. H. G. Barnhart, Chief Engineer, Fuller Engineering Company. Subject: "Pulverized Fuel and Its Uses." The talk was illustrated by lantern slides and was followed by a lively discussion. Attendance 40.

March 19, 1920, Johns Hopkins University. Paper: "High Speed Trans-Oceanic Wireless Reception." Author: Mr. C. H. Hoxie, General Electric Company, Schenectady. The paper gave the steps in the development of a high speed photographic wireless receiver and was illustrated by lantern slides. Attendance 35.

Chicago.—March 4, 1920, Rooms of Western Society of Engineers. Joint meeting with American Society of Mechanical Engineers, Western Railway Club and Western Society of Engineers. Subject: "Some Comments on Present Status of Steam Railroad Electrification." Speaker: Mr. S. T. Dodd, G. E. Co., Schenectady, N. Y. Attendance 250.

March 29, 1920, Western Society of Engineers Hall. Paper: "Transmission of Intelligence." Author: Mr. O. B. Blackwell, A. T. & T. Co., New York. The paper first described in general terms the various means of transmission of intelligence with limitations of each, but was confined chiefly to a general description of the latest development in long distance telephone communication. Attendance 215.

Cleveland.—March 16, 1920, Rooms of Cleveland Engineering Society. Paper: "The Vacuum Tube and Some of its Applications." Author: Mr. J. W. White, G. E. Co., Schenectady, N. Y. The paper was illustrated by lantern slides. Attendance 141.

Denver.—March 27, 1920. After a dinner at the Kenmark Hotel the meeting adjourned to the Denver Gas & Electric Light Company's electrical laboratory, where a very interesting and instructive talk by Mr. H. P. Tewksbury was made on electrical measuring instruments. The talk was illustrated by actual apparatus and demonstrations of some of the tests which are carried out in connection with the meter department. Active discussion followed. Attendance 40.

April 2, 1920, Shirley Hotel, following a dinner in honor of Mr. F. W. Peek, Jr., G. E. Co., Pittsfield, Mass. Mr. Peek spoke on the problems of high tension transmission and pointed out the main factors entering into the development of 210,000 volt transmission lines. Attendance 60.

Detroit-Ann Arbor.—March 12, 1920, Board of Commerce. Round Table Talk. Subject: "The Measurement of Power and the Significance of Power Factor in Single Phase and Three Phase Circuits." The discussion was led by Prof. H. H. Higbie, University of Michigan. Attendance 60.

Erie.—March 10, 1920, Commerce Rooms. Subject: "Vacuum Tubes." Speaker: Mr. W. C. White, G. E. Co., Schenectady, N. Y. Attendance 125.

Fort Wayne.—February 19, 1920, G. E. Club Room. Subject: "Autogenous Welding." Speaker: Mr. Howard Miller, G. E. Co., Fort Wayne. Attendance 40.

Indianapolis-Lafayette.—March 19, 1920, Chamber of Commerce. Subject: "Industrial Efficiency Instruments." Speaker: Mr. D. G. Angus, of the Esterline Co., Indianapolis. Attendance 55.

Ithaca.—February 27, 1920, Franklin Hall, Cornell University. Subject: "Operating Performance of Insulators on a 45,000 Volt System." Speaker: Mr. H. B. Vincent, Management Engineer, Day & Zimmerman, Inc. Attendance 50.

March 5, 1920, Sibley Dome, Cornell University. Joint meeting with the Cornell Branch A. S. M. E. Subject: "The One Best Way" as a solution of the industrial problem. Speaker: Mr. Frank B. Gilbreth. The lecture was illustrated by lantern slides and motion pictures. Attendance 200.

March 19, 1920, Franklin Hall, Cornell University. Subject: "The Manufacture and Application of the Modern Incandescent Lamp." Speaker: Mr. A. L. Powell, Illuminating Engineer, Edison Lamp Works. Attendance 80.

Lynn.—March 3, 1920, G. E. Theatre. Subject: "Latest Developments in Lighting." Speakers: Messrs. G. N. Chamberlain and A. B. Halborson, engineers of the Street Lighting Dept. of the Lynn Works, G. E. Co. The lecture was supplemented by experiments and exhibition of the performance of different types of new apparatus that have been recently developed in the lighting field of the Lynn Works. At the conclusion of the lecture a series of films was shown which were loaned by the War Department showing the service test given to the 60″ searchlight equipment which had been perfected for the Army. Attendance 165.

Milwaukee.—April 8, 1920, Milwaukee Athletic Club. Mr. Tatum, of Cutler-Hammer Mfg. Co., gave an interesting talk on high speed tool steel. Mr. Simon, also of Cutler-Hammer Mfg. Co., gave a brief outline of proposed plan of summer school especially adapted for engineers in professional life who have been out of college long enough to feel the necessity of brushing up on special subjects. Attendance 70.

New York.—March 26, 1920, Engineering Societies Building. Paper: "Gaseous Conduction Light from Low Voltage Circuit." Author: Mr. D. McFarlan Moore. The paper was illustrated by stereopticon slides and demonstrations.

Philadelphia.—April 11, 1920, Engineers' Club. Dinner followed by meeting. Subject: "Traffic Engineering." Speaker: Mr. Frank B. Evans, Jr., Bell Telephone Co. of Pennsylvania. Attendance 75.

Pittsburgh.—February 21, 1920, Chatham Hotel. Joint meeting with Association of Iron & Steel Electrical Engineers. Subject: "Manufacture and Use of Graphic Recording Instruments." Speaker: Prof. J. W. Esterline. Attendance 200.

April 13, 1920, Chamber of Commerce. Subject: "A Modern Coal Mine Hoist Installation." Speaker: Mr. Graham Bright, W. E. & M. Co. Attendance 52.

Pittsfield.—March 18, 1920, Park Club. Subject: "Do we live on the Inside or Outside of the Earth." Speaker: Mr. C. A. S. Howlett, Devine Cushion Wheel Co., Utica, N. Y. Attendance 125.

April 1, 1920, Park Club. Subject: "Power and Transmission." Speaker: Mr. H. H. Dewey, G. E. Co., Schenectady, N. Y. Attendance 100.

Portland.—March 9, 1920, University Club. Business meeting followed by presentation of paper on: "Industrial Development of the Portland District" by Mr. W. H. Crawford, of the Portland Chamber of Commerce. Attendance 19.

Providence.—April 13, 1920, Providence Engineering Society. Organization meeting; election of officers as follows: Chairman, Ralph W. Eaton; Vice-Chairman, Nicholas Stahl; Secretary and Treasurer, Frederick N. Tompkins. Attendance 12.

St. Louis.—February 25, 1920, Engineers' Club. Business meeting, followed by presentation of a paper on: "Design, Manufacture and Use of Graphic Instruments" by Mr. D. J. Angus, of the Esterline Company, of Indianapolis. Attendance 40.

March 31, 1920, Engineers' Club. Papers: "An Automobile Ignition System," by Mr. F. B. Avery, Wagner Electric Manufacturing Company; "Insulating Materials" by Mr. H. A. Richards, Century Electric Company; "Overhead Line Pro-

tection" by Mr. C. H. Kraft, Union Electric Light and Power Company. Attendance 104.

San Francisco.—March 25, 1920. Subject: "War-Time Research." Speaker: Professor Harris J. Ryan. Attendance 90.

Schenectady.—April 2, 1920, Edison Club Hall. Paper: "The Alternating Current Commutator Motor." Author: Mr. B. G. Lamme, Chief Engineer, Westinghouse Elec. & Mfg. Co. Mr. Lamme briefly outlined the history of the development of several of the types of a-c. commutator motor. By using the same method of analysis he compared several types of commutator motors and pointed out the different characteristics of each. By means of blackboard sketches Mr. Lamme reproduced a number of the illustrations given in his paper which was published in the March issue of the JOURNAL By comparison of d-c. motors and a-c. commutator motors it was shown that the problems of commutation were practically the same for both types providing all characteristics are taken into account. Attendance 290.

Seattle.—March 16, 1920, Arctic Club Assembly. Business meeting, followed by presentation of paper on: "Some Elements for Consideration in Valuations" by Mr. Thomas E. Phipps. Attendance 45.

Toronto.—March 19, 1920, Engineers' Club. Business meeting. In place of a formal paper, the meeting took the form of a competitive presentation of original inventions. A committee of judges was appointed, after which the Chairman called on Mr. P. A. Borden to preside, as he had been responsible for all arrangements. Some interesting and very original ideas were presented by several of the members of the Section, and a very active discussion was taken part in by Messrs. Brandon, Wright, Price D'Alton, Hull, Anderson, Cooper, Stephens, Hookway, Mitchell, Bucke, Winter Joyner, Stevenson, Clarke, Lines and Borden. Attendance 92.

March 5, 1920, Engineers' Club. Paper: "General Problems of Operation." Author: Mr. H. C. Don Carlos. Quite a number of very interesting slides were shown and the paper covered a very wide field, including ice troubles at the power house, voltage regulation, insulator failures and changing insulators on live lines, weather conditions as affecting transmission lines and outdoor switching. Attendance 128.

Washington.—March 19, 1920, Willard Hotel. Joint meeting with the Illuminating Engineering Society. Subjects: "R. L. M. Standards of Industrial Lighting" by Mr. W. Harrison National Lamp Works; "Residence Lighting" by Mr. M. Luckiesh, NELA Research Laboratories. Both lectures were illustrated by lantern slides. Attendance 300.

April 13, 1920, Cosmos Club. Business meeting, followed by an illustrated address on the "Design of a Superpower Station" by Mr. Harold Goodwin, Jr. Attendance 105.

Worcester.—April 12, 1920, Worcester Polytechnic Institute. First meeting of Section. Business meeting and election of officers as follows: Chairman, C. R. Oliver; Vice-Chairman, G. M. Hardy; Secretary-Treasurer, Dean J. Locke. Subject: "The Effect of Power Factor and Load Factor upon Central Station Rates" by Prof. C. F. Harding, Purdue Univ. Attendance 102.

PAST BRANCH MEETINGS

University of Arkansas.—February 10, 1920, Physics Bldg. Subjects: "The Electrical Industry" by S. E. Hollabaugh, with slides furnished by G. E. Co.; "The Use of High Pressure Boilers" by R. W. Jacobs. Attendance 21.

February 24, 1920, Engineering Building. Subjects: "Development of the Rotary Converter" by Lance Anderson; "Review of Technical Press" by C. A. Smith; "Labor Problems" by J. B. Rodgerson; "The Uniflow Engine" by Bohart Cowan. Attendance 12.

March 12, 1920, Physics Building. Subject: "The Manufacture and Use of Lightning Arresters and Transformers." Speaker: Mr. H. F. McRell, G. E. Co. Attendance 37.

Armour Institute of Technology.—March 4, 1920, Armour Lecture Room. Business meeting. Attendance 32.

March 18, 1920, Armour Lecture Room. Subjects: 'The Application of Electricity to Mechanical Measurements" by J. W. Naiman, '21; Public Utilities and Their Relation to the Engineering Graduate" by Mr. R. C. Newbury, Denver Gas & Electric Light Co. Attendance 80.

Brooklyn Polytechnic Institute.—March 19, 1920. Subject: "General Testing." Speaker: Mr. F. W. Magalhaes. A demonstration of wireless telephony was given by members of the Radio Branch. Refreshments were served. Attendance 33.

Bucknell University.—April 12, 1920, Bucknell Chapel. Films entitled "The King of the Rails" and "The Electrical Giant" were shown. Attendance 42.

University of California.—February 25, 1920, Mechanics Bldg., Paper: "Inductive Interference in Telephone Circuits." Author: Mr. D. I. Cone, of the Pacific Telephone & Telegraph Co. Attendance 45.

March 10, 1920, Mining Building. Film entitled "Queen of the Waves" was shown. A description of the interesting features of the U. S. S. New Mexico was given by Mr. W. J. Davis, Pacific Coast Engineer of the G. E. Co.

March 24, 1920, Mechanics Building. Paper: "Multiplex Telephony and Telegraphy" by Mr. V. D. Cousins, of the Pacific Telephone & Telegraph Company. Attendance 41.

April 7, 1920, Mechanics Building. Business meeting with election of officers for the coming year as follows: Chairman, E. M. Brown; Vice-Chairman, C. E. Baston; Secretary, R. B. Stewart; Treasurer, R. D. Miller. Attendance 22.

University of Cincinnati.—February 17, 1920, Assembly Hall, Engg. Bldg. Business meeting. Attendance 46.

March 2, 1920, Engg. Bldg. Subject: "Ball Bearings for Electrical Machinery." Speaker: Mr. J. Davis, of the SKF Ball Bearing Co. Attendance 68.

March 16, 1920, Engg. Bldg. Subject: "Fire Alarm System." Speaker: Mr. C. S. Jones, Supt. of Cincinnati Fire Alarm Telegraph Co. Attendance 76.

March 23, 1920, Engg. Bldg. Mr. C. S. Jones repeated the paper given at meeting on March 16, 1920. Attendance 52.

April 7, 1920, Engg. Bldg. Subject: "Refilling burnt out Mazda Lamps, as carried out by a Plant at Franklin, Ohio." Speaker: Mr. F. J. Kepler, '20. Attendance 61.

April 13, 1920, Engg. Bldg. Subject: "Commercial Trouble Shooting." Speaker: Mr. S. F. High, '20. Attendance 69.

University of Colorado.—April 1, 1920, Hale Science Bldg. Mr. F. W. Peek, G. E. Co., gave a talk on the problems of power transmissions, especially at the super-voltages, which was greatly enjoyed by all. Attendance 118.

Georgia School of Technology.—March 18, 1920, Physics Lecture Hall. Subject: "Sales Engineering." Speaker Mr. W. R. Collier, Sales Manager of the Georgia Railway and Power Company. Attendance 42.

March 25, 1920, Y. M. G. A. Auditorium. Illustrated lecture on the "Manufacture of Steel Rails" by Professor R. S. King; and "The Birmingham Inspection Trip" by Professor C. P. Eldred. Attendance 70.

April 8, 1920, Y. M. C. A. Auditorium. Subject: "Electric Ship Propulsion." Speaker: Mr. H. E. Bussey, of the G. E. Co. A film entitled "Queen of the Waves" was then shown, bearing on the subject of the talk. Attendance 75.

State University of Iowa.—February 10, 1920. Physics Bldg. Subject: "The Cedar Rapids Automatic Hydro-Electric Plant" by Geo. Holmes. Attendance 17.

February 22, 1920, Physics Building. Subject: "Electric Drive on the Battleship New Mexico" by K. B. Lambert. Attendance 12.

March 9, 1920, Physics Bldg. Subject: "Electric Motor Controllers" by E. M. Boton, of the W. E. & M. Co.

March 23, 1920, Physics Bldg. Subject: "Electric Fires" by J. B. Demster. Attendance 15.

April 6, 1920, Physics Bldg. Subjects: "The Safety Features of the Birney Safety Car" by L. Rohret; "The Operation of the Magnetic Clutch" by M. L. Banks.

University of Kentucky.—March 22, 1920, Mechanical Hall. Subjects: "Essential Statistics for General Comparison of Steam Power Plant Performance" (Feb. JOURNAL) by N. T. Puckett; "Day Light Saving" (Feb. JOURNAL) by H. T. Weinshank; "The Last Stand of the Reciprocating Engine" (March JOURNAL) by W. M. Wallace; "The Engineer, Employer and Employee" (March JOURNAL) by U. V. Garred; "Constant Potential Series Lighting" (March JOURNAL) by J. D. Wood. Attendance 19.

Kansas State Agricultural College.—March 4, 1920. Subject: "One Phase of the Labor Situation." Speaker: George Clammer. Attendance 78.

March 11, 1920. Election of officers as follows: President, C. F. Joss; Vice-President, E. G. Abbott; Secretary, R. S. Breese; Treasurer, M. Stigers. Subject: "Transmission Line Construction." Speaker: Kenneth Houser. Attendance 65.

March 18, 1920. Subjects: "Advertising the Engineering College over the State" by Martin Soule; "What Makes a Successful Man" by Dr. J. R. Macarthur. Attendance 73.

April 1, 1920. Subjects: "Progress of the Electrical Field" by Mr. Posey; "Use of Our Mistakes" by Mr. Fisher; "Why Kansas State Agricultural College should change its name to Kansas State College" by G. R. Rush; "Electric Propelling Machinery on the U. S. S. *Tennessee*" by Lloyd Zimmerman; extemporaneous talk, C. E. Reid. Attendance 58.

Lehigh University.—March 12, 1920, Physics Bldg. Subject: "Central Station Development" by Mr. N. E. Funk, Philadelphia Electric Company. Social hour and refreshments. Attendance 56.

April 15, 1920, Physics Bldg. Subject: "Superpower Station for the Union Francaise" by Harold D. Goodwin, Jr., G. E. Co. Attendance 90.

University of Maine.—March 4, 1920, Lord Hall. Business Meeting, followed by presentation of a paper on "Electric Propulsion of Ships" by Lawrence Merrow. Professor Barrow spoke on the present situation in New England regarding electric power supplies. Attendance 19.

Massachusetts Institute of Technology.—March 23, 1920." Subject: "General Problems of Telephone Engineering. Speaker: Mr. G. K. Manson, N. E. T. & T. Co. Attendance 50.

Michigan Agricultural College.—March 11, 1920, R. E. Olds' Hall. Election of officers as follows: Chairman, M. B. Rann; Secretary, J. F. Van Ark. Attendance 18.

University of Michigan.—March 25, 1920, Engg. Bldg. Business meeting, followed by a talk by Mr. H. S. Osborne, of the A. T. & T. Co. on "Electrical Transmission of Thought and Power. Attendance 65.

School of Engineering of Milwaukee.—March 19, 1920. Subject: "Heat Treatment of Steel." Speaker: "Mr. G. W. Esau, Chief Engineer of the Modern Heat Treating Steel Company. Attendance 90.

University of North Carolina.—February 2, 1920. Talks as follows: "Storage Batteries" by M. E. Lake; "Operation of Storage Batteries" by G. T. Finger; "High Tension Insulators" by C. D. Blair; "Electricity on the Farm" by C. G. Lancaster. Attendance 40.

March 1, 1920.—Business meeting and election of officers. Talks as follows: "Commutation of D. C. machines" by P. C. Smith; "Air Gaps of D. C. Machines" by T. E. Hinson; "Testing of D. C. Machines" by A. B. Right; "Rating of D. C. Machines" by L. V. Milton. Attendance 52.

March 26, 1920. Illustrated lecture by C. S. Coler, of W. E. & M. Co. Attendance 38.

Ohio Northern University.—March 18, 1920, Dukes Memorial. Subjects: "The Development of Hydro-Electric Plants" by Mr. J. W. Ulrey; "Machine Gun Ammunition Testing" by R. L. Quigley; "Signal Corps Work" by M. E. Elder. Attendance 19.

University of Oklahoma.—March 25, 1920. Subject: "Modern Developments in Radio Telephony" Speaker: Prof. Wm. A. Schriever. Attendance 34.

Oregon Agricultural College.—February 26, 1920. Business meeting. The following films were shown: "The Conviction of Si Smith;" "The Electrical Giant" and "The Potters Wheel." Attendance 53.

University of Pittsburgh.—January 27, 1920. Subject: "The History of the Transmission of Electricity." Speaker: Mr. P. M. Lincoln. Attendance 15.

February 17, 1920. Election of officers as follows: Chairman, W. F. Young; Vice-Chairman, C. R. McGann; Secretary, J. C. Wolfe. Attendance 14.

March 2, 1920. Subject: "The History of Electricity." Speaker: Prof. H. E. Dyche. Attendance 21.

March 9, 1920. Subject: "Automatic Substation." Speaker: Mr. James C. Wolfe. Attendance 21.

March 16, 1920. Illustrated Paper "Electrification of the C. M. & St. P. Railroad." Speaker: Mr. G. B. Anderson. Attendance 21.

March 23, 1920. Paper: "Eastern Power Development." Speaker: Mr. W. F. Young. Attendance 17.

March 30, 1920. Subject: "The Electrification of the Norfolk and Western Railroad." Speaker: Mr. W. T. Askin. Attendance 19.

April 6, 1920. Subject: "Review of the Electrical Development for the Year 1919." Speaker: Mr. J. F. Keller. Attendance 28.

Purdue University.—March 8, 1920. Business meeting, followed by presentation of the following papers: "The Westinghouse Company and Its Work" by Mr. Kottman; "Work on the Duquesne Power Plant" by Mr. Skinner; "Electrolysis" by Mr. C. F. Mitchell '20, and G. C. Schleter '20. Attendance 100.

March 15, 1920. Business meeting, and election of officers as follows: Chairman, W. A. Clark; Vice-Chairman, E. R. Moore; Secretary, G. R. Dittwe; Treasurer, J. H. Dagenhart. Paper: "Telephone Transmission" by Mr. H. S. Osborne. Attendance 105.

April 6, 1920. Paper: "The Cash Register." Speaker: Mr. W. E. Carr. Attendance 45.

Stanford University.—March 10, 1920. Mech. Engg. Bldg. Illustrated lecture by Professor Harris J. Ryan on the Los Angeles Aqueduct. Attendance 38.

March 15, 1920. Election of officers as follows: Chairman, Raymond Lewelling; Secretary-Treasurer, Harry P. Wickersham. Professor Harris J. Ryan spoke on "The Hisotry of the Development of the A. I. E. E. from 1900 to 1920. Attendance 14.

University of Virginia.—April 1, 1920, Mechanical Laboratory. The following addresses were delivered: "Signal Characteristics and Operation" by Mr. Wagner; short address by Dr. Carl Hering approving and encouraging the establishment of a course in railway signaling at the university of Virginia; short address by Mr. Livers, President of C. &. A. Railway, on practical experiences in electrical work, both constructing and operating. Attendance 22.

Washington State College.—March 12, 1920. Film entitled "The Spirit of Progress" was shown. Attendance 42.

University of Wisconsin.—January 22, 1920. Engg. Bldg. Business meeting, followed by a talk by Mr. Miller, of the Wisconsin Rate Commission, on "Procedure in Establishing Rates for Public Utilities in Wisconsin." Attendance 33.

February 25, 1920, Engg. Bldg. Three short talks by Students were given as follows: "Graduate Test Course at Westinghouse Elec. & Mfg. Co., by D. R. Lamont; "Opportunitise in Railway Signalling" by Harold P. S. Day; "Test Course for Graduates at G. E. Co." by R. R. Knoerr. Attendance 43.

March 10, 1920, Engg. Bldg. Business meeting followed by a talk by Mr. Garber, of the Western Electric Co. on "Manufacturing Conditions at the Hawthorne Works. Attendance 65.

March 19, 1920. Subject: General Features of Telephone Transmission with Particular reference to its relation to Power Transmission. Speaker: Mr. Harold S. Osborne, of the A. T. & T. Co. Attendance 59.

Yale University.—February 18, 1920, Dunham Lab. of E. E. Business meeting. Attendance 14.

March 19, 1920. Dunham Lab. of E. E. Illustrated lecture by Mr. Charles Rufus Harte on "Power Transmission Lines." Attendance 60.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED APRIL 9, 1920

Adams, Harvey P., Manager, A. & B. Company, McAllen, Texas.

Adams, Howard H., Cadet Engineer, United Improvement Co., 1401 Arch St., Philadelphia, Pa.

Adams, Myron W., Engineer, Operating Dept., New England Power Co., Millbury, Mass.

Aitchison, Willard L., Inspector, Western Electric Co. Inc., 203 Broadway, New York; res., 92 Monroe St., Brooklyn, N. Y.

Anderson, E. W., Asst. Inspector, Public Service Co. of Northern Illinois, Evanston; res., 1254 N. La Salle St., Chicago, Ill.

Anderson, Wm., Prof. of Physics & Elec. Engg., Rhode Island State College, Kingston, R. I.

Anderson, William F., Junior Engineer, Toledo Railways & Light Co.; res., 304 18th St., Toledo, Ohio.

Andrews, Fred A., Station Supt., New England Power Co., Hoosac Tunnel, Mass.

Antoniono, Caesar, Foreman of Electrical Construction, Chicago, North Shore & Milwaukee Railroad, 72 W. Adams St., Chicago, Ill.

Arledge, George H., Asst. Engineer (Steam), War Department, Supply Div.; res., 2628 Garfield St., N. W., Washington, D. C.

Arnold, Oscar M., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Aslaniar, Coffing W., Electrical Laboratory Man, Standardizing & Testing Depts., Boston Electric Illuminating Co., Boston, Mass.

*Bailey, George N., Asst. to Supt. of Steam Power, New England Power Co., 35 Harvard St., Worcester, Mass.

Bain, James W., Demonstrator in Elec. Engineering, McGill University, Montreal, Quebec, Canada.

Ball, Frederick Widmer, Electrical Instructor, Soldiers' Aid Commission, University of Toronto; res., 78 Herbert Ave., Toronto, Ont.

*Ballinger, John G., Electrician, Hydro-Electric Power Commission, Streetsville, Ontario, Can.

Bangs, Philip C., Junior Engineer (Transmission), Southern Bell Tel. & Tel. Co.; res., 29 Albemarle Ave., Atlanta, Ga.

Barcus, Miner, Draftsman, American Transformer Co., Newark; res., 20 Ivanhoe Terrace, East Orange, N. J.

*Barden, Harold E., Asst. Production Engineer, Southern California Edison Co., Edison Building, Los Angeles, Cal.

Barnes, Stanley M., Central Office Inspector, Michigan State Telephone Co.; res., 1086 Ellery St., Detroit, Mich.

Barney, Howard S., Dist. Supt., Chester County Light & Power Co., Kennett Square, Penn.

Barret, Charles E., Machinery Salesman, James Clark, Jr., Electric Co., 520 W. Main St., Louisville; res., Anchorage, Ky.

Barron, Edward F., Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Barry, Thomas A., Engineering Dept., General Electric Co., 84 State St., Boston, Mass.

*Bayle, Russell M., Electrical Tester, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1219 Mill St., Wilkinsburg, Pa.

Beard, Harry F., Electrical Foreman, American International Shipbuilding Corp., Hog Island, Pa.

Beechinor, Herbert M., Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

Bendel, Emil H., Head of Engineering Dept., California Polytechnic School, San Luis Obispo, Cal.

Bender, Louis B., Captain, Signal Corps, U. S. A.; res., 34 Rodman St., Boston 30, Mass.

Benjamin, Webster W., Power Engineer, Western Light & Power Co., Boulder, Colo.

Bennett, Rolland H., Division Transmission Engineer, The Pacific Tel. & Tel. Co., San Francisco, Cal.

Bergen, Harold B., Junior Engineer, Henry L. Doherty & Co., 60 Wall St., New York; res., 589 Putnam Ave., Brooklyn, N. Y.

Blackwell, William I., Sales Agent, General Electric Co., 627 State Mutual Bldg., Worcester, Mass.

Bland, Henry, Telephone Engineer, Central Office, Western Electric Co., Hawthorne; res., 1208 W. 64th St., Chicago, Ill.

Blue, Frederick R., Engineer, Plant Dept., New York Telephone Co.; res., 1180 President St., Brooklyn, N. Y.

Bodey, Norman A., Supt., Engineering Dept., William H. Luden Mfg. Corp.; res., 126 Windsor St., Reading, Penn.

Bolton, John I. N., General Engineering, 13 Clyde St., Toronto, Ont., Canada.

Bozzi, Mario T., Chief Electrician & Motor Expert, The Acme Wire Co.; res., 12 Lines St., New Haven, Conn.

Bradley, Francis H., Equipment Engineer, So. New England Telephone Co.; res., 462 First Ave., West Haven, Conn.

Bradner, James P., Major, A. S. A. P., Officer U. S. Army; res., 1912 R St., N. W., Washington, D. C.

Brodhun, Carl P., Asst. Gen. Sales Manager, Hazard Mfg. Co., Wilkes-Barre, Pa.

Broe, Edgar P., Dept. of Development & Research, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

*Brooks, Forrest E., Telephone Engr., Engineering Dept., New York Telephone Co., 203 Broadway, New York, N. Y.

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*Burnett, William, Jr., Electrical Engineer, Peabody Coal Co., Mine 18, W. Frankfort, Ill.

Burrows, Walter G., Telephony Engineering, New York Telephone Co., 203 Broadway, New York, N. Y.

Carlson, Carl F., Supervisor, The Cortland Electric Co., Inc.; res., 1715 Woodbine St., Brooklyn, N. Y.

Carnachan, Robert S., Electrical Draftsman, Bureau of Yards & Docks, Navy Dept.; res., 1513 Meridian Place, N. W., Washington, D. C.

Carpenter, Leslie S., Telephone Engineering, New York Telephone Co., New York, N. Y.; res., Chatham, N. J.

Champlin, Franklin J., Engineer in charge, Voltage Regulator Dept., General Electric Co., Pittsfield, Mass.

Chapman, V. J., Testman, General Electric Co.; res., 141 Fairview Ave., Schenectady, N. Y.

Chesnut, Edward F., Chief Instructor, Applied Electricity, Dept. of Soldier's Civil Re-establishment; res., 71 Walker St., Toronto, Ont.

Chute, Norman T., Manager, Hartford Office, The Lincoln Electric Co., 54 Church St., Hartford, Conn.

Clark, Henry W., Senior Engineer, Potomac Electric Power Co.; res., 2020, "O" St., N. W., Washington, D. C.

Clarke, Albert H., Sales Engineer, Canadian General Electric Co. Ltd., 212 King St. West, Toronto. Ont.

Cleary, Leo H., Electrical Designing Draftsman, Bureau of Yards & Docks, Navy Dept.; res., 43 Rhode Island Ave., N. W., Washington, D. C.

Cleary, William J., Telephone Engineering, New York Telephone Co., New York; res., 70 So. 9th St., Brooklyn, N. Y.

Clements, Chauncey H., Cable Supervisor, Southern New England Telephone Co.; res., 25 Irving St., New Haven, Conn.

Cleon, Hyman, Laboratory Asst., Lubrication Div., Bureau of Standards, Washington, D. C.

*Cobb, Cecil C., Electrical Construction Foreman, Oklahoma Railway Co.; res., 209 W. 2nd St., Oklahoma City, Okla.
Collins, Everett B., Asst. Elec. Engineer, New England Power Co., 35 Harvard St., Worcester, Mass.
Collins, Raymond P., Supervisor of Maintenance, Southern New England Telephone Co., New Haven; res., 38 Glendale St., Whitneyville, Conn.
Comstock, William W., Junior Electrical Engineer, Public Service Commission, 1st Dist., 49 Lafayette St., New York, N. Y.
*Conklin, Silas H., Asst. Electrical Engineer, Bureau of Standards, Washington, D. C.
Cooper, Geoffrey T., Checker of Electrical Design, Harry M. Hope Engineering Co., 185 Devonshire St., Boston, Mass.
Cowles, Willard B., Radio Research Laboratory, Connecticut Tel. & Elec. Co., 464 Colony St., Meriden, Conn.
Cox, Louis T., Development Engineer, (Auto Telephone), Western Electric Co.; res., 562 W. 144th St., New York, N. Y.
Creasey, John W., District Inspector, American Tel. & Tel. Co., 204 Telephone Bldg., Kansas City, Mo.
Cromwell, George F., Transmission & Protection Engineer, Wisconsin Telephone Co., 418 Broadway, Milwaukee, Wis.
*Crump, Samuel Lee, Electrical Engineer, Denver Gas & Electric Light Co., Denver, Colo.
Cuff, Paul S., Draftsman, New York Edison Co.; res., 200 W. 109th St., New York, N. Y.
Darling, Charles W., Officer in charge, Marconi Station s/s Hochelaga; Marconi Wireless Tel. Co. of Canada, 173 William St., Montreal, Canada.
Davis, Albert I., Construction Foreman, West Penn Power Co.; res., 225 Painter St., Greensburg, Pa.
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Day, Bernhard F. J., Managing Director, The Day Engineering Bureau, Thanet House, Strand, London, Eng.
*Deane, Tsung Yao, Telephone Engineer, China Electric Co., Shanghai, China.
Dennison, Allan, Foreman Electrician, Canadian Explosives Ltd., Nobel, Ontario, Can.
De Nyse, Charles R., Jr., Substation Operator, United Electric Light & Power Co., New York; res., 1836 Church St., Richmond Hill, N. Y.
De Penning, Victor H., Electrician, E. L. Knight Electric Co., 449 Washington St.; res., 141 E. 34th St., Portland, Ore.
Dodge, John W., Division Equipment Inspector, Western Union Telegraph Co., Bankers Investment Bldg., San Francisco, Cal.
*Dorpat, Martin H., Designer of Manual Control Apparatus, Cutler-Hammer Mfg. Co., 12th & St. Paul Sts., Milwaukee, Wis.
Dortch, G. L., Merchant, Planter & Engineer, Power Equipment Co., 213 E. Markham St., Little Rock, Ark.
*Drake, Charles P., Supt., Edison Steam Plant, Wis-Minn. Light & Power Co., La Crosse, Wis.
Droesch, Louis A., Instructor, Dept. of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J.
Duncan, P. M., Electrical Engineer, Allis-Chalmers Mfg. Co., West Allis; res., 3631 Park Hill Ave., Milwaukee, Wis.
Duncan, William Bryan, Draftsman, San Joaquin Light & Power Corp., Bakersfield, Cal.
Dunton, Ernest W., Chief Electrical Engineer, Anglo-Saxon Petroleum Co. Ltd., London, England; res., Miri, Singapore, India.
Eales, Malcolm A. L., Asst. to Operating Engineer, New England Power Co., Worcester; res., 4 Chestnut Park, Melrose, Mass.
Ebaugh, John H., Sales Representative, Allis-Chalmers Mfg. Co., Denver, Colo.
Edgerton, Rupert L., General Toll Wire Chief, Southern New England Telephone Co.; res., 42 William St., New Haven, Conn.
Ehlers, Paul, Chief Electrician, Zimmerman Steel Co., Bettendorf; res., 619 Gaines St., Davenport, Iowa.
Elebash, Karl S., Electrical Engineer & Contractor, Elebash Elec. Co., Tuscaloosa, Ala.
English, Charles L., Electrical Engineer, Ansonia Electrical Co.; res., 70 So. Cliff St., Ansonia, Conn.
Eshelman, Paul B., Electrical Engineer, Fidelity Electric Co., 332 N. Arch St., Lancaster, Pa.
Fay, Richard D., Associated with H. V. Hayes, 84 State St., Boston; res., 20 Coolidge Hill Road, Cambridge, Mass.
Ferguson, Muirhead T., Electrical Asst. to Plant Engineer, Halifax Shipyards, Ltd.; res., 55 Cornwallis St., Halifax, N. S.
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Flath, Earl H., Asst. Professor of Physics and Electrical Engineering, University of Alabama, University, Ala.
Flynn, William N., Plant Electrician, Atlantic Corp., Portsmouth; res., 7 Hancock St., Dover, N. H.
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*Freehafer, Fred K., Engineering Asst., The Bell Telephone Co. of Penn., Philadelphia; res., Lansdowne, Pa.
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Furuki, Masumitsu, Student Engineer, Testing Dept., General Electric Co., Schenectady; res., Scotia, N. Y.
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Gass, Thomas A., Sales Manager, Canada Wire & Cable Co., Ltd., Toronto, Ont.
George Everett E., Valuation Engineer, A. L. Drum & Co., Chicago; res., 230 N. 2nd St., Highland Park, Ill.
*Gibson, Archie B., Manager, Casino Technical Night School, E. Pittsburgh, Pa.
Gillett, Francis E., Supt., The Depew & Lancaster Light, Power & Conduit Co.; res., 12 Holland Ave., Lancaster, N. Y.
*Glasgow, Roy S., Instructor in Electrical Engineering, Washington University; res., 3966 Arsenal St., St. Louis, Mo.
*Godshalk, Ernest L., Engineering Dept., Counties Gas & Electric Co., 212 De Kalb St., Norristown, Pa.
Goldberg, Israel, Electrician, Hughes Electric Heating Co.; res., 9 Beatrice St., Toronto, Ont.
Goldsman, Jack L., Radio Engineer, Emil J. Simon, 217 Broadway, New York, N. Y.
*Goldston, Leonard, Senior Student in Elec. Engg., Brooklyn Polytechnic Institute; res., 117 So. 4th St., Brooklyn, N. Y.
Golladay, Lawrence R., Electrical Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1435 Penn Ave., Wilkinsburg, Pa.
Goodnough, Rex E., Central Office Engineer, Western Electric Co., Hawthorne; res., 5122 W. 24th Place, Cicero, Ill.
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*Haman, Donald A., Instructor, Pratt Institute, Brooklyn, N. Y.
Harrison, William H., Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Hartman, Fred, Chief Electrician, Cumberland Coal Co., Albert, Tucker Co., W. Va.
*Hartung, Arthur E., Sales Engineer, Century Electric Co.; res., 5352 Vernon Ave., St. Louis, Mo.
Hastings, Milton B., Secretary & Sales Engineer, A .H. Winter Joyner Ltd., 100 Wellington St. W., Toronto, Ont.
*Hawker, Clifford F., Asst. Electrical Engineer, Dayton Power & Light Co., Dayton, Ohio.
Hecker, Arthur D., Electrical Foreman, American International Shipbuilding Corp., Hog Island, Pa.
Hemenway, Robert A., Meter tester, Worcester Electric Light Co.; res., 22 Davidson Road, Worcester, Mass.
Henderson, John W. G., Draftsman, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
*Herrle, Jacob N., Jr., Asst. Foreman, Metropolitan Engineering Co.; res., 664 Madison St., Brooklyn, N. Y.
Hickey, Charles E., Supt. of Interior Construction, N. Y. & Queens Electric Light & Power Co., Bridge Plaza, Long Island City, N. Y.
Hill, Clarence, Elec. Foreman, American International Shipbuilding Corp., Hog Island, Pa.
Hill, Harold C., Motor Specialist, International General Electric Co., Inc.; res., 126 Parkwood Blvd., Schenectady, N. Y.
Hine, Donald F., Student, Graduate School, Yale University, 70 Trumbull St., New Haven, Conn.
Ho, Molin, Graduate Student, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 329 Barnes St., Wilkinsburg, Pa.

HOARE, STEPHEN C., Standardizing Laboratory, General Electric Co.; res., 80 Park St., W. Lynn, Mass.
HODGES, FRANK E., Engineer, New York Telephone Co., 15 Dey St., New York, N. Y.
HOELZLE, FRANK C., Chief Electrical Draftsman, New York Shipbuilding Corp., Camden, N. J.
HOKE, CHARLES C., Junior Engineer, Union Electric Light & Power Co.; res., 3812 Castleman Ave., St. Louis, Mo.
HOLIHAN, THOMAS D., Electrical Sales Engineer, Syracuse Lighting Co., 335 S. Warren St., Syracuse, N. Y.
HOLLIDGE, GEORGE M., Construction Foreman, San Francisco Dist., Pacific Gas & Electric Co., 1822 San Antonia Ave., Alameda, Cal.
HOUSTON, ROBERT, Resident Electrical Engineer Water Conservation & Irrigation Commission, Leeton, N. S. Wales, Australia.
*HOYLE, EARLE R., Electrician, Texas Construction Co., Interurban Bldg., Dallas, Texas.
HUFF, BENJAMIN L., Distribution Engineer, Consumers Power Co.; res., 202 Palmer Avenue, Jackson, Mich.
HUGHES, RUSSELL H., Engineering Asst., New York Telephone Co., 15 Dey St.; res., 438 W. 116th St., New York, N. Y.
HUYLER, ROLLIN M., Electrical Construction Man, United Electric Light & Power Co., 514 West 147th St., New York, N. Y.
HYMANS, FREDERICK, Engineer with Otis Elevator Co., 11th Ave. & 26th St., New York, N. Y.; res., Glen Ridge, N. J.
IRWIN, J. HARVEY, Salesman, Aluminum Company of America, 1500 Westminster Bldg., Chicago, Ill.
JAMES, EARL S., Chief Electrician, Oklahoma Gas & Electric Co., 18-20 W. Noble, Oklahoma City, Okla.
JEANNE, PAUL A., Asst. Electrical Engineer, Mountain States Tel. & Tel. Co., Denver, Colo.
JENKINS, JOHN R., Service Dept., Cutler-Hammer Mfg. Co., New York; res., 715 Lott Ave., Union Course, N. Y.
JESSEN, CHRISTIAN, Chief Electrical Mechanic, Bureau of Illumination, City of Milwaukee; res., 659 New York Ave., Milwaukee, Wis.
*JOHNSON, ROBERT H., Sales Engineer, National Carbon Co., 431 S. Dearborn St., Chicago, Ill.
JONES, BENSON M., General Engineering Division, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
JONES, CARL H., Lieutenant, U. S. Navy; res., 2465 Broadway, New York, N. Y.
KARKER, EARL C., Instructor of Physics & Electricity, Univ. of Rochester; res., 151 Genesee St., Rochester, N. Y.
KARLSEN, EDWARD V., Electrician, Union Gas & Electric Co., West End Station, Cincinnati, Ohio.
KELLE, ARTHUR C., Electrical Engineer, 75 State St., Boston; res., 26 Dana Ave., Hyde Park, Mass.
KENNEDY, CLIFFORD W., Research Engineer, M. S. Wright Co.; res., 8 Oberlin St., Worcester, Mass.
KIMBALL, MERRILL J., Division Switchboard Engineer, Traffic Dept., Pittsburgh Div., The Bell Telephone Co. of Penn., 416 7th Ave., Pittsburgh, Pa.
KING, IRVING CLARENCE, System Operator, Empire Gas & Electric Company, Auburn, N. Y.
KITA, ICHIMATSU, Testing Dept., General Electric Co., Schenectady; res., 147 Riverside Ave., Scotia, N. Y.
*KODIL, CHARLES E., Operator, Bureau of Power & Light, City of Los Angeles, Cal.
*LEE, EWE AIK, 309 E. Garfield Boulevard, Chicago, Ill.
LEGG, JOSEPH W., Electrical Engineer, (Research & Development) Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
LEXA, GEORGE J., Asst. Electrical Engineer, Pawling & Harnischfeger Co.; res., 1056 25th St., Milwaukee, Wis.
*LINCOLN, JOHN C., Foreman of Construction work, Delco-Light Co.; res., 411 Buttles Ave., Columbus, Ohio.
*LITTLEFIELD, MAURICE G., Thompson Electric Welding Co., Lynn; 33 Cedar Hill Terrace, Swampscott, Mass.
*LIVERGOOD, HOMER, Elec. Constr. Foreman, Engineering Dept., General Electric Co., Witherspoon Bldg., Philadelphia, Pa.
LOCKERBIE, EARL M., Branch Manager, Lincoln Electric Company of Cleveland, Ohio, 721 University Bldg., Syracuse, N. Y.
LOHR, HERMAN, Director of the "N. V. Provinciale Geldersche Ekectriciteits Maatschappy" Utresctsche stratt, Arnhem, Holland.
LOWRY, RAY S., Electrical Engineer, Newton Steel Co., Newton Falls, Ohio.
LOYNES, OWEN H., Electrical Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
LUKE, GEORGE E., Railway Motor Design Section, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
LUNNY, JAMES E., Buyer, W. R. Grace & Co., New York; res., 508 16th St., Brooklyn, N. Y.
KNIGHT, HENRY A., Supervisor of Wires, City of Worcester, 11 City Hall, Worcester, Mass.
KRUEGER, CARL H., Transmission & Protection Engineer, Wisconsin Telephone Co., 418 Broadway, Milwaukee, Wis.
KUHN, PAUL R., Electrical Engineer, Penn. Central Light & Power Co.; res., 813 Green Ave., Altoona, Pa.
KUMEILIKE, LORENZ LEI, Radio Electrician (First class), U. S. Naval Radio Laboratory, Mare Island; res., 942 Third St., Napa, Cal.
LAMPE, J. HAROLD, Electrical Engineer, Winchester Repeating Arms Co., 16 York Square, New Haven, Conn.
*LANKTON, WILLIAM W., Foreman in Charge of Electrical Dept., Detroit Copper & Brass Rolling Mills; res., 619 Hubbard Ave., Detroit, Mich.
LAPLANTE, ERNEST G., Electric Installation & Maintainence, Wood Electric Construction Co., Lynn, Mass.
*LA ROQUE, HAROLD B., Graduate Student, Yale University, 68 Whalley Ave., New Haven, Conn.
LASH, LELAND E., Supt., Oklahoma Gas & Electric Co., 112 N. Broadway, Oklahoma City, Okla.
LASKEY, WILLIAM G., Engineer, Western Electric Co. Inc., 463 West St., New York, N. Y.
LAW, CLARENCE L., Manager, Bureau of Illuminating Engineering, N. Y. Edison Co., Irving Place & 15th St., New York, N. Y.
LAWRENCE, ROGER C., Electrical Engineer, American Steel & Wire Co., 94 Grove St., Worcester, Mass.
LAYCOCK, CHARLES H., Radio Draftsman, U. S. Navy Yard, 9 Blackwood St., Boston, Mass.
LEBO, WILLIAM F., Engineer, Public Service Comm. of Indiana; res., 1037 N. Belleview Place, Indianapolis, Ind.
LYON, WILLIAM R., Instructor in Electrical Engineering, University of Wisconsin, Engineering Bldg., Madison, Wis.
MADDOCK, EDWIN C., Supt., Electrical Construction, Chevrolet Motors, Oshawa, Ontario, Can.
MASON, DONALD T., P. B. X. Repairman, Central Union Telephone Co.; res., 94 Wick Place, Youngstown, Ohio.
MCCHESNEY, ROBERT W., District Manager, Harry Alexander, Inc.; res., 827 8th St., N. E. Washington, D. C.
MCCORDICK, ARTHUR S., Sales Engineer, Canadian General Electric Co., 212 King St. West, Toronto Ontario.
MCKERROW, ALAN DRUMMOND, Electriacl Designer, New England Power Co., 35 Harvard St., Worcester, Mass.
MCLAREN, DUNCAN L., Engineering Dept., Canadian General Elecrtic Co., Ltd.; res., 291 Stewart St., Peterboro, Ont.
MCORLLY, JOSEPH, Draughtsman in Charge of Development Section, Railway & Industrial Engineering Co., Greensburg, Pa.
*MILLER, CHARLES A., Meterman, Light Dept., City Hall, Tacoma, Wash.
MITZENIUS, WALTER L., Electrical Engineer, New York & Queens Elec. Lt. & Pr. Co., Bridge Plaza, Long Island City, N. Y.
MUNOZ, ALPHONSE, Armature Winder, General Chemical Co.; res., Overlook Colony, Claymont, Del.
*MURATA, MOTOSABURO, 102 West 123rd St., New York, N. Y.
*NAYLOR, JOHN M., Draftsman, The Millville Mfg. Co.; res., 303 High St., Millville, N. J.
NEAHR, WILL C., Electrical & Designing Engineer, The Protective Signal Mfg. Co., 1429 18th St., Denver, Colo.
NEWMAN, WILLARD L., Telephone Equipment Engineering, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
OLDHAM, EDWARD C., Electrical Engineering, New England Power Co., 35 Harvard St., Worcester, Mass.
O'NEIL, WILLIAM J., Chief Operator, Margaret St. Substation, Turners Falls Power & Electric Co., Springfield, Mass.
O'NEILL, FRANK H., Chief Electrician, Monongahela Valley Traction Co.; res., Y. M. C. A., Fairmont, W. Va.
OSBURN, WILLIAM, Floor Electrician & Foreman of Construction of Central Station, Union Gas & Electric Co., Cincinnati, Ohio.
OVERBEY, FRANK E., Service & Inspection, Cutler-Hammer Mfg. Co., 50 Church St., New York, N. Y.
PACKARD, ANSEL A., Superintendent, The Connecticut Power Co., Middletown, Conn.
PARMER, MARION CURTIS, Chief Electrician, Beech Bottom Power Co. Wheeling; res. Wellsburg, W. Va.
PATTERSON, CHARLES L., Designer of Electrical Machinery, Fessenden Engineering Laboratory, 185 Franklin St., Boston, Mass.
PAYNE WILLIAM H., Engineer, The Pittsburgh Electric Furnace Corp., Pittsburgh; res., Carnegie Hotel, Clariton, Pa.
PENDER, PAUL S., Erecting Engineer, Printing Equipment Dept., The Cutler-Hammer Mfg. Co., Milwaukee, Wis.
PENNINGTON, JOHN F., Tester, Construction Dept., Georgia Railway & Power Co., 445 Electric & Gas Bldg., Atlanta, Ga.
PERKINS, E. EVERETT, JR., Tester, Westinghouse Elec. & Mfg.

Co., E. Pittsburgh; res., 419 Whitney Ave., Wilkinsburg, Pa.
Petrie, Albert E., Telephone Engineer, Western Electric Co., 463 West St., New York, N. Y.; res., E. Orange, N. J.
*Pette, Allen D., Asst. Steam & Elec. Engineer, International Harvester Co., McCormick Works; res., 2135 W. Adams St., Chicago, Ill.
Phelps, Leverne R., Electrical Supt., Atlas Crucible Steel Co.; res., 412 Mullett St., Dunkirk, N. Y.
Phillips, Charles O., Electrical Draftsman, Stone & Webster Co., 916 Chestnut St., Philadelphia, Pa.
Phinney, Harry L., Equipment Engineer, The Pacific Tel. & Tel. Co., 461 Market St., San Francisco, Cal.
Plaisance, Stanley F. X., Construction Foreman, General Electric Co., Monadnock Block, Chicago, Ill.
Polachek, Zoltan H., Manager, Manufacturers Engineering Co., 1133 Broadway, New York, N. Y.
Pope, Harry M., Commercial Engineering Dept., New York Telephone Co., 15 Dey St., New York, N. Y.
*Postles, Findlay J., Electrical Instructor, New York Electrical School, 39 W. 17th St., New York, N. Y.
Poston, Virgil, Supt. of Operation, New York & Queens Electric Light & Power Co., Bridge Plaza, Long Island City, N. Y.
Pottinger, Clarence A., Electrical Engineer, Bureau of Illuminating Service, City of Milwaukee, City Hall, Milwaukee, Wis.
Powell, Joel W., Telephone Engineer, The Pacific Tel. & Tel. Co., 620 Sheldon Bldg., San Francisco, Cal.
Prosser, William E., Industrial Heating Engineer, Union Electric Light & Power Co., St. Louis, Mo.
Purinton, Ralph B., Electrical Engineer, General Electric Co., Monadnock Bldg., Chicago, Ill.
Ranges, John E., Engineer, Western Electric Co., 463 West St.; res., 79 Jane St., New York, N. Y.
Rathke, C. George, Draftsman, Connecticut Light & Power Co.; res., 31 Central Ave., Waterbury, Conn.
Reese, Clarence B., Gen. Electrical Foreman, Construction Dept., Braden Copper Co., Rancagua, Chile, S. A.
Reich, Walter J., Wire & Cable Engineering, General Electric Co., Schenectady; res., 365 Guy Park Ave., Amsterdam, N. Y.
Richardson, Simeon W., with F. R. Weller, 503 Hibbs Bldg., Washington, D. C.
Rives, Tom C., Asst. City Electrician; res., 214 Grove St., Montgomery, Ala.
Roberts, Clinton V., Electrical Construction Dept., General Electric Co.; res., 724 Rosedale Ave., Erie, Pa.
Rocchetti, Joseph, Chief Engineer, Manitoba Power Commission, New Parliament Bldgs., Winnipeg, Manitoba.
Rosenzweig, Fred M., Engineer, Roth Bros. & Co., Adams & Loomis Sts., Chicago, Ill.
Runyon, William McCurdy, Chief Inspector, E. V. Hartford, Inc., 143 Morgan St., Jersey City; res., Stelton, N. J.
Rusmissell, Charles T., Chief Electrician, McDowell Coal & Coke Co., McDowell, W. Va.
*Rutan, Everett J., Foreman, Test Dept., N. Y. Edison Co., New York; res., 4630 Ridge Ave., Glen Morris, N. Y.
*Ryan, Clarke L., Construction Engineer, Nebraska Telephone Co.; res., 606 N. 33rd St., Omaha, Neb.
Salt, Lloyd B., Asst. Research Engineer, B. F. Sturtevant Co., Hyde Park; res., 11 Van Brunt Ave., Dedham, Mass.
*Sawyer, Leon G., Electrical Engineer, Eisemann Magneto Co.; res., 463 40th St., Brooklyn, N. Y.
Sawyer, Lee A., Field Engineer, Research Corporation, 63 Wall St., New York, N. Y.
Scheffer, Robert E., Student Engineer, General Electric Co.; res., 244 Union St., Schenectady, N. Y.
Schelleng, John C., Engineering Dept., Western Electric Co., 463 West St., New York, N. Y.
Schwarberg, Harry J., Foreman, Substation, Union Gas & Electric Co., 4th & Plum St., Cincinnati, Ohio.
Selzer, Carl A., Chief Electrician, Leeds & Northrup Co. of Philadelphia, 4901 Stenton Ave., Philadelphia, Pa.
Shaffer, Irwin, Electrical Designing Engineer, B. F. Goodrich Co., Akron; res., 235 S. 3rd St., Cuyahoga Falls, Ohio.
*Sheadel, James B., Supt., Traction, Light & Power Co.; res., 1511 Arrow Ave., Anderson, Ind.
Shechtell, Joseph, Electrical Tester, Edison Electric Illuminating Co. of Boston, 1165 Massachusetts Ave., Boston, Mass.
Sherrerd, George, Jr., Commercial Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Sinner, Harry C., Chief Electrical Maintenance Engineer, Bergner & Engel Brewing Co.; res., 1330 N. Dover St., Philadelphia, Pa.
Smith, J. Frank, District Manager, Blackmer Rotary Pump Co., 1119 Real Estate Trust Bldg., Philadelphia, Pa.
Smith, John F., Tester, The United Electric Light & Power Co.-New York; res., 2406 Bedford Ave., Brooklyn, N. Y.
Spero, B. E., President, Spero Electrical Mfg. Co., E. 33rd & Woodland Sts., Cleveland, Ohio.
Sprague, Arthur B., Foreman, Testing Dept., Worcester Electric Light Co., 66 Faraday St., Worcester, Mass.
Stayner, Charles M., Supt. of Lines & Substations, Bamberger Electric Railroad, Salt Lake City; res., Farmington, Utah.
Stein, Rudolph H., Quarterman Instrument Maker, Navy Yard, New York; res., 589 98th St., Woodhaven, N. Y.
Stevens, John C., Consulting Hydraulic Engineer, Spalding Building, Portland, Ore.
Stier, H. Douglas, District Sales Manager, Railway & Industrial Engineering Co. 602 Monadnock Block, Chicago, Ill.
Stone, J. Waldo, Sales Agent, General Electric Co., New York, N. Y.; res., 9 Carteret St., Upper Montclair, N. J.
Suydam, William H., Jr., Tester, New York Edison Co., 92 Vandam St., New York; res., 645 Delaware Place, Brooklyn, N. Y.
Templeman, Daniel R., Asst. in Research Dept., M. S. Wright Company; res. 63 Charlotte St., Worcester, Mass.
*Terrell, Phillip A., Electrician, Alabama Power Co.; res., 1114 Tuscaloosa Ave., W. E., Birmingham, Ala.
*Teschner, Albert, In Charge of Elec. Construction & Maintenance, The Texas Co., Bayonne, N. J.
Thompson, Thomas C., Factory Manager, Automatic Electric Co., 1001 W. Van Buren St., Chicago, Ill.
Tillman, Stephen J. N., Chief Electrician, Old Dominion Copper Co., Globe, Ariz.
Tobiessen, Emanuel, Electrical Engineer, Allis-Chalmers Mfg. Co.; res., 774, 74th Ave., West Allis, Wis.
Tornquist, Earl L., Asst. Inspector, Public Service Co. of Northern Illinois, 230 N. Genesee St. Waukegan, Ill.
Townsend, George L., 1st Lieut., Officer in Charge, Signal Corps Research Laboratory, Bureau of Standards; res., 98 Chestnut St., Washington, D. C.
*Townsend, Wisner R., Purchasing Dept., American Sugar Refining Co.; res., 420 W. 116th St., New York, N. Y.
Trojan, Ervin J., Asst. Testing Engineer, Commonwealth Edison Co., 28 No. Market St., Chicago, Ill.
Truman, Joseph K., Power Plant Operator, (Canyon Ferry Plant), Montana Power Co., Canyon Ferry, Mont.
Tsujii, Makoto, Engineer, Furukawa & Co. Ltd., 120 Broadway, New York, N. Y.
Tyler, Charles H., Electrical Construction, U. S. Naval Ordnance Plant, South Charleston, W. Va.
Van Horn, Alfred R., Designing Engineer & Inventor, Trumbull Electric Mfg. Co., Plainville, Conn.
Van Thun, James R., Electrical Leaderman, American International Shipbuilding Corp., Hog Island; res., 1516 N. 27th St., Philadelphia, Pa.
Walter, Hollis, Asst. Stabilizer Engineer, Sperry Gyroscope Co., Manhattan Bridge Plaza, Brooklyn, N. Y.
Wegel, Raymond L., Western Electric Co., Inc., 463 West St., New York, N. Y.
Welch, Paul V., Engineer, Dept. of Development & Research, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
Weller, Clifford T., Electrical Engineer, General Engineering Laboratory, General Electric Co., Schenectady, N. Y.
Wenzel, August F., Telephone Engineer, Rochester Telephone Co.; res., 385 Parsells Ave., Rochester, N. Y.
White, Allan Joseph, Transmission & Protection Engr., Southwestern Bell Tel. Co., Little Rock, Ark.
Whitehurst, Roland, Sales Engineer, Electric Storage Battery Co.; res., 2024 Morris Ave., New York, N. Y.
Wilcox, Harry K., Electrician, Gillespie Motor Co.; res., 341 Getty Ave., Paterson, N. J.
Wilkes, Frederic, Superintendent, Nearyville Electric Light & Power Co., Nearyville, Mo.
*Williams, F. George, Asst. Electrical Engineer, Pressed Steel Car Co., McKees Rocks, Pa.
Witt, Stanley, Tester, Century Electric Co., 1827 Pine St., St. Louis, Mo.
Woellmer, Louis A., Electrical Engineer, Canadian Engineering Agency, 115 Broadway, New York, N. Y.
Wolf, Wyatt H., Office Engineer & Correspondent, Allis-Chalmers Mfg. Co., 50 Church St., New York, N. Y.
Woodman, Arthur P., Polyphase Meter Tester, Public Service Co. of Northern Illinois; res., 1123 Noyes St., Evanston, Ill.
Woodward, Alan A., Junior Engineer, Toledo Railways & Light Co., 1904 Jefferson Ave., Toledo, Ohio.
Wright, Fred E., Asst. to Supt., Line Construction, Westchester Lighting Co., Mt. Vernon, N. Y.
Wu, Wei-Yoh, Student, Graduate School, Columbia University; res., 530 W. 112th St., New York, N. Y.

YANG, TSAO-SHING, Teacher, Syracuse University, 119 Stadium Place, Syracuse, N. Y.
ZINCKGRAF, RAYMUND G., Inspector, Motive Power Dept., Interborough Rapid Transit Co.; res., 539 E. 147th St., New York, N. Y.
Total 301
*Former enrolled student.

ASSOCIATES RE-ELECTED APRIL 9, 1920

FRIEND, LEONARD, Electrical Foreman, Toledo Shipbuilding Co.; res., 1022 Superior St., Toledo, Ohio.
LEE, EVERETT S., Engineer, General Engineering Laboratory, General Electric Co.; res., 967 Maple Ave., Schenectady, N. Y.
KERR, DAVID J., Supt. of Power, Champion Fibre Co., Canton, N. C.
MYERS, ALEXANDER M., Chief Electrician, Standard Underground Cable Co., Perth Amboy, N. J.
MOORE, CHARLES R., Telephone Engineer, Western Electric Co., 463 West St., New York, N. Y.
WATERHOUSE, JAMES K., Supt., L. I. City Dist., New York & Queens Elec. Lt. & Pr. Co., Queens Plaza North, Long Island City, N. Y.
YOUNG, RUSSELL, Resident Engineer, Atlantic Refining Co.; res., 717 So. Frazier St., Philadelphia, Pa.

MEMBERS ELECTED APRIL 9, 1902

BECHTOL, HARVEY W., Brush Engineer, National Carbon Company, Inc., Cleveland, Ohio.
BROWN, LEWIS B., Asst. to Chief Draftsman, Public Service Electric Co., Newark; res., Chatham, N. J.
BROWN, WENDELL S., Engineer, F. P. Sheldon & Son, 1009 Hospital Trust Bldg., Providence, R. I.
DAVIES, STANLEY F., Consulting Electrical Engineer, 101 Park Ave., New York, N. Y.
EDWARDS, JOHN H., Electrical Engineer, Elkhorn Piney Coal Mining Co., 211 Robson-Prichard Bldg., Huntington, W. Va.
HAMMOND, WILLIAM P., Asst. Engineer, Georgia Railway & Power Co., Atlanta, Ga.
JAMES, BERTRAM, Sales Engineer, Moloney Electric Co. of Canada, Ltd., Toronto, Ont.
JEFFERY, JOSEPH A., President, Jeffery-Dewitt Co.; and Jeffery-Dewitt Insulator Co., Detroit, Mich.
*JOHNSON, LEWIS H., Systems Development Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.; res., Madison, N. J.
*LEONARD, RUSSELL E., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
LEONIDA, DIMITRIE, General Manager, "Energia," & Director "Scoala de Electricioni & Mechanici," Str. Salcamilor 11, Bucharest, Roumania.
MASEK, JAMES C., Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 724, 51st St., Milwaukee, Wis.
O'HARA, GEORGE D., Consulting Engineer, O'Hara & Shaw, 1015-17 Phelan Bldg., San Francisco, Cal.
PIGMAN, GEORGE R., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
RICHARDSON, FRANK D., Engineer, Inside Plant, Long Lines Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
SHANNONHOUSE, GEORGE G., Electrical Engineer, Du Pont Engineering Co., Wilmington, Del.; res., 435 Woodward Ave., Detroit, Mich.
*SMITH, HARRY A., Division Traffic Engineer, Western Union Telegraph Co., 914 Transportation Bldg., Atlanta, Ga.
SPATES, THOMAS G., Asst. to Gen. Supt., New York & Queens Elec. Lt. & Pr. Co., Elec. Bldg., Bridge Plaza North, Long Island City, N. Y.
WOLLEY, CHARLES E., Supt. of Factory & Vice-President, James Clark Jr. Electric Co.; res., 1014 Everett Ave., Louisville, Ky.
* Former enrolled students

FELLOWS ELECTED APRIL 9, 1920

McLEER, CHARLES B., Engineer, Electric Transport Co., 165 Broadway, New York, N. Y.
THOMAS, JAMES WINTHROP, Engineer, United Gas & Electric Engg. Corp., 61 Broadway, New York, N. Y.

TRANSFERRED APRIL 9, 1920

To Grade of Fellow

BLISS, LOUIS D., President, Bliss Electrical School, Takoma Park, Washington, D. C.
GRAY, CLYDE D., Electrical Engineer, J. G. White Engineering Corp., New York, N. Y.

To Grade of Member

BOYKIN, RICHARD M., Vice-President and General Manager, North Coast Power Co., Portland, Ore.
CANDY, ALBERT M., General Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
GASKILL, WALTER W., Consulting and Sales Engineering, Boston, Mass.
HAYES, CLIFTON R., Engineering Manager, Charles H. Tenney & Co., Boston, Mass.
HENKLE, JOSEPH C., Supt. Meters & Construction, Portland Railway, Light & Power Co., Portland, Ore.
HOFFMANN, CHARLES B., Assistant Professor of Electrical Engineering, University of Cincinnati, Cincinnati, O.
JOHNSTON, A. LANGSTAFF, JR., Lt. Comdr., U. S. N. R. F., Senior Asst. Inspector of Machinery, U. S. Navy, Newport News, Va.
KARTAK, FRANZ A., Professor of Electrical Engineering, School of Engineering of Milwaukee, Milwaukee, Wis.
LAMB, GILBERT C., Electrical Engineer, Engineering Div., E. I. du Pont de Nemours & Co., Wilmington, Del.
NOYES, JOHN D., Sales Engineer, Detroit Edison Co., Detroit Mich.
PECK EMERSON P., Gen'l Supt. Elec. Dept. Utica Gas & Electric Co., Utica, N. Y.
THOMAS, GEORGE N., Electrical Engineer, Canadian General Electric Co. Ltd., Toronto, Ont.
WERWATH, OSCAR, President, School of Engineering of Milwaukee, Milwaukee, Wis.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at a meeting held on April 6, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

FRASER, DANIEL M., Estimating Engineer, Canadian General Electric Co. Ltd., Toronto, Ont.
SNOOK, H. CLYDE, Electrical Engineer, Western Electric Co., New York, N. Y.

To Grade of Member

BAKER, HENRY S., In Charge Detail Apparatus, Ontario Power Co., Niagara Falls, Ont.
BENNETT, CLAUDIUS E., Asst. Chief Engineer, Riegos y Fuerzo del Ebro, Barcelona, Spain.
BENSON, ROBERT J., Power Engineer, Wagner Electrical Mfg. Co., St. Louis, Mo.
CLINGERMAN, BYRON H., Managing Power Engineer, B. F. Goodrich Co., Akron, O.
DU VALL, W. CLINTON, Associate Professor of Electrical Engineering, University of Colorado, Boulder, Colo.
GROWDON, JAMES P., Asst. General Superintendent, Northwestern Electric Co., Portland, Ore.
GHOSH, SURENDRA N., Acting Chief Electrical Engineer, Tata Iron & Steel Co., Ltd., Jamshedpur, India.
JAMES, WILLIAM F., Sales Engineer, Westinghouse Electric & Mfg. Co., Philadelphia, Pa.
LOCKE, DEAN J., Electrical Engineer, with Albert S. Richey, Worcester, Mass.
LODYGUINE, ALEXANDER, Inspector Incoming Electrical Material, Sperry Gyroscope Co., Brooklyn, N. Y.
SARA, RICHARD A., Partner, C. A. Sara, Montreal, Que.
TODD, WILLIAM B., Asst. Electrical Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del.
TUTTLE, ELBERT B., Asst. Engineer, Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.
WATERHOUSE, JAMES K., Supt. L. I. City District, N. Y. & Queens Electric Light & Power Co., Long Island City, N. Y.
WHITNEY, RICH D., Associate Professor of Electrical Engineering, Syracuse University, Syracuse, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member, objecting to the election of any of these candidates should so inform the Secretary before April 30, 1920.

Alender, Walter A., Chicago, Ill.
Anderson, Burt T., Hoboken, N. J.
Anderson, Russell E., Chicago, Ill.
Argabrite, Harry H., Denver, Colo.
Arnold, Samuel, 3rd, Ambridge, Pa.
Baerer, Eugene A., Tamaqua, Pa.
Bailey, Walter L., Detroit, Mich.
Bair, D. Arthur, Chicago, Ill.
Bason, George F., Utica, N. Y.
Bateman, Sidney J., Newark, N. J.
Batsel, Max C., Camp Alfred Vail, N. J.
Bender, Joseph G., New York, N. Y.
Berry, Thomas D., Toronto, Ont.
Blye, Paul W., New York, N. Y.
Britton, Emmet N., San Francisco, Cal.
Bowman, Herman N., New York, N. Y.
Bradley, Daniel L., Philadelphia, Pa.
Brown, Harry C., Toronto, Ont.
Brown, Irwin E., Northampton, Pa.
Burnham, David W., Toronto, Ont.
Butler, Abner I., Chicago, Ill.
Cahoon, William H., New York, N. Y.
Cameron, James R., Bluefield, W. Va.
Campbell, Louis O., Chicago, Ill.
Chapel, Harrie D., Milwaukee, Wis.
Chapple, Edward A., Toronto, Ont.
Chisholm, William J., New York, N. Y.
Christiansen, Kay A., E. Pittsburgh, Pa.
Clamer, Guilliam H., (Member), Philadelphia, Pa.
Cloger, Eaton J., Cambridge, Mass.
Cloke, Philip R., State College, Pa.
Coffey, Frank J., Giant, Cal.
Conlon, Willard S., Camp Upton, N. Y.
Cook, Ralph J., Cleveland, Ohio
Cotter, William F., New York, N. Y.
Cover, Leo G., Nela Park, Cleveland, Ohio
Cox, George C., Cullowhee, N. C.
Craig, Berrywick S., (Member), Port Arthur, Texas
Cutler, Ralph D., Hartford, Conn.
DeBeech, Albert V., New York, N. Y.
De Silvia, Fred E., Seattle, Wash.
Dibble, John, Toronto, Ont.
Dinwiddie, James A., Toledo, Ohio
Dippell, Howard W., New York, N. Y.
Duffin, Charles G., San Francisco, Cal.
Dunn, Edward J., Angola, Ind.
Durhan, Barry G., Chicago, Ill.
Eaton, Cecil L., Seattle, Wash.
Ellis, Gould, Canton, Ohio
Ellyson, Douglas, Chicago, Ill.
Evans, Benjamin D., Jr., New York, N. Y.
Everson, Russell B., Passaic, N. J.
Farrington, John F., New York, N. Y.
Fast, John E., Chicago, Ill.
Flammer, Howard A., New York, N. Y.
Flynn, Thomas F., Albany, N. Y.
Forrest, Elbert E., Gary, Indiana
Freepartner, John J., Seattle, Wash.
Fernald, John M., Boston, Mass.
Frick, George H., Akron, Ohio
Furtick, Grover C., Philadelphia, Pa.
Garratt, Graham L., Toronto, Ont.
Garver, Paul L., E. Pittsburgh, Pa.
Gastonguay, Emile, Thana, Alaska
Gibson, Earl S., New York, N. Y.
Giles, Raymond B., San Francisco, Cal.
Gorbakowsky, Ilia, New York, N. Y.
Goss, C. H., Jackson, Mich.
Graham, Frank H., New York, N. Y.
Grant, Henry W., Everett, Wash.
Greenhill, Douglas C., Westmount, Montreal, Que.
Gregson, Montruvila E., New York, N. Y.
Haight, Aaron L., Long Island City, N. Y.
Hamilton, Walter L., Holyoke, Mass.
Hannon, Frank R., Metuchen, N. J.
Harman, Richard A., Columbus, Ohio
Hashimoto, Seiji, New York, N. Y.
Heth, William A., Milwaukee, Wis.
Heuser, J. U., Chicago, Ill.
Hill, Curtiss L., Tacoma, Wash.
Hockaday, Olin S., Dallas, Texas
Hill, Herbert R., Toronto, Ont.
Holland, John R., Chicago, Ill.
Holmes, Tyler L., Denver, Colo.
Hoot, Harold T., New York, N. Y.
Horton, J. Warren, New York, N. Y.
Huie, Oliver J., (Member), Atlanta, Ga.
Ironside, George A., Hamilton, Ont.
Jewell, Leonard, Toronto, Ont.
Johnson, Arthur C. K., Chicago, Ill.
Johnson, Charles W., E. Pittsburgh, Pa.
Johnson, Raymond H., Bridgeport, Conn.
Joho, Ernest C., New York, N. Y.
Jones, Clinton, Pittsfield, Mass.
Jones, Philip T., New York, N. Y.
Jones, Ray V., New York, N. Y.
Jones, Robert A., Schenectady, N. Y.
Jordan, Thomas, Arthur, Utah
Julius, Dietrich J., Meridian, Miss.
Karcher, E. Kenneth, Utica, N. Y.
Keese, Foster D., Scranton, Pa.
Kinsman, Fred, Detroit, Mich.
Kinsman, Russell C., Tuscaloosa, Ala.
Kistler, William J., Hauto, Pa.
Klein, Harry R., Allentown, Pa.
Knapp, Frank E., Detroit, Mich.
Knox, Carlos C., Cleveland, Ohio
Knutz, Jay H., Chicago, Ill.
Koch, Marshall M., New York, N. Y.
Kvall, Andrew B. S., New York, N. Y.
Lansford, Willis R., Washington, D. C.
Lawler, Elliott R., Toronto, Ont.
Lee, Robert E., Tacoma, Wash.
Leonard Leon H., Milwaukee, Wis.
Lewis, Howard A., New York, N. Y.
Livermore, L. S., Seattle, Wash.
Lobeck, Adolf J., New York, N. Y.
Lowe, J. Cornelius, Montreal, Que.
MacMurphy, Franklin, New York, N. Y.
Mason, Jordan A., Chicago, Ill.
Mathes, Carl F., Raleigh, N. C.
Mathis, Andrew W., Seattle, Wash.
McCullough, Phillip M., Omaha, Neb.
McDonald, James W., Jr., Boston, Mass.
McEwen, H. J., Calgary, Alta., Can.
McFarland, William E., Cleveland, Ohio
McKay, Fred M., Athens, Ohio
McKenzie, Robert M., Toronto, Ont.
McNett, Richard F., Springfield, Ohio

McPherson, Harry L., Seattle, Wash.
Meagher, James N., Halifax, N. S.
Meister, George J., Ampere, N. J.
Mejia, Julio E., Troy, N. Y.
Middleton, Elliott W., Allentown, Pa.
Millikin, Keith C., Midland, Ont.
Mission, Georges, Paris, France
Mitchell, Sam E., Seattle, Wash.
Mong, Clifford E., San Francisco, Cal.
More, Thomas R., McMinnville, Ore.
Moss, Malcolm W., Boston, Mass.
Mulford, Allen, Schenectady, N. Y.
Mulholland, Brendan F., Toronto, Ont.
Murdock, Alfred W., Toronto, Ont.
Nash, De Lloyd D., Elizabeth, N. J.
Neil, Harry A., Lyons, N. Y.
Nicholson, Albert C., Chicago, Ill.
Nixon, Norman J., Hamilton, Ont.
Olson, William J., Seattle, Wash.
Ott, Voyle D., Racine, Wis.
Patterson, Robert D., New York, N. Y.
Pearson, Edgar F., (Member), Portland, Ore.
Pearson, Oscar A., Chicago, Ill.
Perkins, Hammond M., Lynn, Mass.
Peterson, Harold D., Brooklyn, N. Y.
Phillips, Edwin T., Norwich, Conn.
Platt, Bruce C., Toronto, Ont.
Plowmann, Carroll S., Elizabethport, N. J.
Popky, Charles H., Yonkers, N. Y.
Potts, Melvon, Plainville, Conn.
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Redding, W. Chester, New York, N. Y.
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Reier, George C., New York, N. Y.
Reneker, Robert L., Detroit, Mich.
Reynolds, Frank J., Hartford, Conn.
Ribal, E. A. H., Chicago, Ill.
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Rockey, James K., New York, N. Y.
Rothwell, Hugh D., Toronto, Ont.
Schafer, J. Peter, New York, N. Y.
Schiller, Avery R., Lowell, Mass.
Seely, Roy A., New York, N. Y.
Seem, Warren P., Altoona, Pa.
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Shea, T. E., Cambridge, Mass.
Shearer, Harold H., (Member), New York, N. Y.
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Shirk, William B., Bethlehem, Pa.
Simons, Robert, Philadelphia, Pa.
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Sinclair, Ovid E., Crystal Lake, Ill.
Smalley, David D., Santa Maria, Cal.
Smedley, Harry J., Chicago, Ill.
Smith, A. Z., Tacoma, Wash.
Smith, Fred W., Springfield, Ohio
Snook, Ward H., Paulding, Ohio
Snow, Frank S., Portsmouth, N. H.
Snyder, Fred H., Chicago, Ill.
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Spinney, Parker T., Yonkers, N. Y.
Stamm, Otto E., New York, N. Y.
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Stoddard, Fred M., Cincinnati, Ohio
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Thompson, Stephen W., St. Louis, Mo.
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Wilking, Emil, Chicago, Ill.
Williams, Floyd E., Hibbing, Minn.
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Wood, Herbert A., Toronto, Ont.
Wood, Thomas S., (Member), Atlanta, Ga.
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Total 228.

Foreign

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STUDENTS ENROLLED
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11282 Brennen, William J., Carnegie Institute of Technology
11283 Flocos, George N., Carnegie Institute of Technology
11284 Allen, James G., Carnegie Institute of Technology
11285 Goldberg, Herman, Carnegie Institute of Technology
11286 Ichikura, Thomas S., Carnegie Institute of Technology
11287 Sterba, Ernest J., State University of Iowa
11288 Whisler, George M., Carnegie Institute of Technology
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11291 Reid, Ricklef A., Lehigh University
11292 Smith, Ardo C., School of Applied Industries

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11296 Branch, William H., Georgia School of Technology
11297 Childs, John W., Georgia School of Technology
11298 Daniel, Homer N., Georgia School of Technology
11299 Des Portes, Calvin J., Georgia School of Technology
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11301 Holcombe, James B., Georgia School of Technology
11302 Hooker, Scroop D., Georgia School of Technology
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11304 Jacobs, Hubert L., Georgia School of Technology
11305 Lynch, Rolyn E., Georgia School of Technology
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11311 Stokes, Harry G., Georgia School of Technology
11312 Watkins, Henry E., Georgia School of Technology
11313 Watson, Ross O., Georgia School of Technology
11314 Whittaker, Alan D., Georgia School of Technology
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11317 Conroy, Martin J., Worcester Polytechnic Inst.
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11320 Bossart, Paul N., Columbia University
11321 Richardson, Max C., Columbia University
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11324 Priest, Conan A., University of Maine
11325 Trouant, Virgil E., University of Maine
11326 Young, Jacob, Mass. Institute of Technology
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11329 Wiggins, Gilbert N., New Hampshire College
11330 Pingree, George N., New Hampshire State College
11331 Watson, Wesley, New Hampshire State College
11332 Pike, Otis W., New Hampshire State College
11333 Scammon, Chester A., New Hampshire State College
11334 Weigel, Frederick A., New Hampshire State College
11335 Herrick, Roswell H., University of Wisconsin
11336 Bohrman, Heer, Ohio State University
11337 Spence, Arthur W., California Inst. of Technology
11338 Harding, Arthur G., Texas A. & M. College
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11340 Hennequin, J. H., School of Engg. of Milwaukee
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11358 Hoffman, Howard V., Michigan Agricultural College
11359 Van Ark, James F., Michigan Agricultural College
11360 Premo, Joseph G., Michigan Agricultural College
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11362 Otten, Harry C., Stevens Institute of Technology
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11364 Jenness, Roger R., Worcester Polytechnic Institute
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11366 Alves, Orlando F., Ohio Northern University
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11369 Champion, Edgar F., Georgia School of Technology
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11371 Boyd, Frank E., University of New Mexico
11372 Kinghorn, Archibald H., Jr., Mass. Inst. of Technology
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11374 Smith, Irving R., Worcester Polytechnic Institute
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11376 Rowbottom, Edwin D., University of Pittsburgh
11377 McCurdy, Wallace H., University of Pittsburgh
11378 Askin, William J., University of Pittsburgh
11379 Young, Walter F., University of Pittsburgh
11380 McGann, Clement R., University of Pittsburgh
11381 Anderson, George B., University of Pittsburgh
11382 Jones, William B., University of Pittsburgh
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11391 Sandiford, Raymond B., Mass. Inst. of Technology
11392 Rowe, Norman O., Iowa State College
11393 Pereira, Richard G., Worcester Polytechnic Institute
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11400 Petit, Francis W., Rutgers College
11401 Boyden, Frederick A., Wentworth Institute
11402 Merriman, Arthur G., Mass. Institute of Technology
11403 Dressler, Carl A., New York Electrical School
11404 Dittwe, George R., Purdue University
11405 Anderson, Harold W., University of Kansas
11406 Chen, Lr, Worcester Polytechnic Institute
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11409 Wyche, Philip L., University of California
11410 Johnson, George D., University of California
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11412 Smart, Willard R., University of California
11413 Landon, James G., University of California
11414 Nelson, Cyril B., University of California
11415 Miller, Rexwell D., University of California
11416 Brown, Earle McK., University of California
11417 Kower, Eugene, University of California
11418 Krasny, Frank C., University of California
11419 Andrews, Clarence A., University of California
11420 Tays, George, University of California
11421 Baston, Cyril E., University of California
11422 Herkner, Clarence G., University of California
11423 Larrecq, Maurice J., University of California
11424 McAllister, Chester B., University of California
11425 Langdon, Andrew, University of California
11426 Blanchard, L. C., University of California
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11428 Youngstrom, Nels C., University of California
11429 Stewart, Ronald B., University of California
11430 Wollam, Gerald Z., University of California
11431 Sullivan, Charles B., University of Virginia
11432 Spooner, Howard M., Rutgers College
11433 Chapman, Robert E., Worcester Polytechnic Inst.
11434 Jones, Walter L., Jr., University of Missouri
11435 Morgan, Frank L., Iowa State College

Total 154.

THE CORONA VOLTMETER AND THE ELECTRIC STRENGTH OF AIR

(*Continued from page 444*)

(*c*) *Comparison of Kenotrons with Commutator*. With the connections shown in Fig. 1, since the kenotron conducts in only one direction, the galvanometer receives a unidirectional pulsating current, the successive pulses being separated by time intervals of one-half period. The same conditions may be obtained in the galvanometer by the method shown in Fig. 3, the resistance R_1 being connected straight to ground and the synchronous commutator being connected as a shunt suppressor, *i. e.*, so that the galvanometer is short-circuited during alternate half-cycles. With fixed conditions in the high-tension circuit therefore both these methods should give the same galvanometer reading. In the experiments recorded in the following Table II, the voltage was set at the corona-forming value for a 0.955-cm. (0.376-in.) diameter rod in the corona voltmeter, for each of the two wave forms pertaining to the two methods of connection of the transformer primaries. The table gives for each method of connection first the readings leading to the commutator setting for maximum galvanometer deflection, and this is done using the galvanometer both as complete rectifier and as half-wave suppressor. It is seen that these two sets of readings are closely in the relation 2 to 1, and that the commutator setting is indicated to within one and one-half electrical degrees. The readings at maximum setting are then given and directly below them the corresponding kenotron readings. It is seen that there is excellent agreement particularly when the full rectification readings are included. A further interesting observation was made in connecting the galvanometer and commutator as shunt suppressor across each of the resistances R_1 and R_2 of Fig. 1 in turn, using the maximum brush settings and other conditions of Table II. For one of the resistances the full galvanometer deflections of Table II were obtained, but for the other the mean of the right and left readings of the galvanometer was accurately zero, as is to be expected since for the half wave during which the kenotron conducts the galvanometer is short-circuited by the commutator. This observation also indicates the absence of reverse currents due to inequalities in the voltage wave.

TABLE II.
COMPARISON OF READINGS WITH KENOTRONS AND WITH COMMUTATOR.

Brush setting degrees	Transformer primaries in parallel					
	Full wave			Half wave		
	Left	Right	Mean	Left	Right	Mean
90	11.99	12.01	12.00	6.07	5.98	6.02
93	12.00	12.07	12.03	6.09	5.99	6.04
96	12.00	12.07	12.03	6.09	5.98	6.03
99	11.93	12.02	11.97	6.01	5.99	6.00
94.5	11.99	12.07	6.01 × 2	6.08	5.98	6.03
With kenotrons				5.99	6.01	6.00
	Transformer primaries in series.					
72	11.82	11.90	11.86	6.01	5.89	5.95
75	11.92	12.02	11.97	6.04	5.93	5.98
78	11.98	12.07	12.00	6.08	5.94	6.01
81	11.97	12.03	12.20	6.07	5.97	6.03
84	11.89	12.00	11.94	6.02	5.93	5.97
79.5	11.96	12.07	6.01 × 2	6.07	5.97	6.02
With kenotrons						6.01
				5.99	6.01	6.00
				5.98	6.02	6.00

(*d*) *Calibration of Galvanometer*. The galvanometer used for measuring the charging current of the air condenser was a late American type d'Arsonval read by telescope and scale. Its constants were as follows: resistance 115 ohms; sensitivity 40 megohms; free period 9.5 seconds; critical damping resistance 560 ohms. Throughout all the observations the galvanometer was shunted with 560 ohms and the combination used in series with 10^6 ohms for measuring the potential drop across the resistances R_1 and R_2 in Fig. 1. Since the maximum voltage is measured through the current in R_1 or R_2, it is obviously of the first importance that the galvanometer be accurately calibrated. The calibration directly in amperes was effected by passing continuous current through R_1 or R_2 and measuring this current through the resulting potential drop over a resistance of 499 ohms always in this auxiliary circuit; the potential drop was measured on a precision potentiometer in terms of a Weston cell. The value of the resistance was determined to within 1/25 of 1 per cent by comparison with certified laboratory standards. Two certified Weston cells were used, one checking the constancy of that in use with the potentiometer; at the end of the observations their values were equal to the fourth decimal.

The galvanometer was calibrated for every series of observations and usually at approximately the scale reading pertaining to the particular charging current being measured; see Table VII.

In order to investigate a possible error due to the pulsating character of the galvanometer current when the instrument is calibrated for continuous current, an extensive series of observations was made using the commutator for breaking up continuous current and for cutting out alternate half waves of alternating current. These experiments have been described in another paper,[10] and show that when the galvanometer

is connected as in Fig. 1 or Fig. 3 the calibration with continuous current is accurately the same as that with pulsating current whether rectangular or of approximately sine shape.

(e) *Resistance of Ground Connection.* Since the central section of the air condenser is connected to ground through the resistance and kenotron circuits of Fig. 1, two questions arise as to the effect of the resistance of these circuits on the charging current of the condenser. First, if the resistance of this circuit is sufficiently high the voltage across the terminals of the condenser may be appreciably lower than the total voltage between high-tension terminal and ground; and second, if the resistance in question is sufficiently high, suitable adjustment must be made to ensure equal potential between the central section of the condenser and the guard rings, or otherwise the current in the kenotron circuit would not be that due to the capacity between the high-voltage member of the condenser and the central section of the grounded member alone.

With reference to the first of these questions, the calculated capacity of the central member of the condenser is 8.262×10^{-11} farads. The measured value is 8.286×10^{-11} farads, (see paragraph (h) below). The corresponding reactance at 60 cycles is therefore 3.2×10^7 ohms. The resistances R_1 and R_2, Fig. 1, were 2000 ohms each throughout the experiments. The equivalent resistance of one kenotron varies with its filament current and also with the current that the kenotron is transmitting. The values of these resistances were determined by taking the volt-ampere characteristics of the kenotrons with continuous currents. It is not thought necessary to reproduce these readings here, as the characteristics of the kenotron are well-known. The maximum value of kenotron resistance obtaining in the experiments was approximatley 4000 ohms.

The filament currents of the two kenotrons were always adjusted to the same value as indicated by a direct-reading continuous-current instrument. Slight variations in the filament current have no effect on the transmitting power of the kenotron and only produce small variations in the equivalent resistance of the kenotron.

Consequently the maximum aggregate resistance in the ground circuit of the central section at any time was approximately 6000 ohms. This noninductive resistance is in series with the capacity reactance of 3.21×10^7 ohms of the central section of the condenser and has therefore a quite negligible effect either in elevating the potential of the outer member of the condenser above ground, or in reducing the voltage at the condenser terminal below the full applied value.

The accuracy of the above deductions was tested by connecting the central section of the condenser to ground through resistance only and similarly the two guard rings in parallel to ground through resistance only. The voltage drop over these resistances was studied by means of the commutator and galvanometer. The results showed that the voltage drop over each resistance was accurately proportional to its value. They also showed that the values so measured on either resistance were independent of the value of the other resistance within the range 0 to 10,000 ohms, the study not being carried further.

With reference to the second question raised above, namely, as to the effect of a difference of potential between the guard rings and the central section on the values of the charging current to ground from the central section, it would appear from the foregoing that, since the difference of potential between the two members is negligibly small, and furthermore since the capacity between them is also small, no influence on the charging current of the central section would be found even if the guard rings were connected directly to ground. However, it was thought best to investigate the matter experimentally and also to determine the proper value of resistance to connect between the guard rings and ground in order to ensure that the guard rings are at the same potential as the central member. The results of this study are given in Table III.

Referring to Table III and Fig. 1, the first column gives the value of the resistance R_3 between guard

TABLE III.
INFLUENCE OF RESISTANCE IN GROUND CONNECTION OF CONDENSER.

R_3	Volts over *D-F.*			Volts over R_2			Volts over R_2			Volts over R_3		
	Left	Right	Mean	Left	Right	Mean	Left	Right	Mean	Left	Right	Mean
9999	10.7	10.73	10.71	3.3	3.35	3.32	3.8	3.35	3.32	17.9	18.1	18.0
5970	10.73	10.82	10.77	3.29	3.36	3.32	3.29	3.36	3.32	10.68	10.8	10.79
0	10.73	10.82	10.77	3.29	3.36	3.32	3.29	3.36	3.32	0.1	0.1	0.

$R_1 = R_2 = 2000$ ohms. Filament current 2.75 amperes.

rings and ground; the next three columns right, left and mean readings of the galvanometer connected between D and F of Fig. 1 using the commutator for rectification; the next three columns voltage over R_2; and the next three that over R_1 both without use of commutator; and the last three columns the voltage over R_3 with the aid of the commutator. These results show that the voltage between the point D and ground and the voltages over the resistances R_1 and R_2 are all independent of the value of the resistance R_3 up to 10,000 ohms. Furthermore they show that the guard rings are brought to the same potential as the central section when connected to ground through a resistance R_3 of 5,970 ohms. R_3 was kept at this value throughout the course of the work.

(*f*) *Measurement of Frequency.* The value of frequency enters directly from Formula (**4**) into the expression for the maximum value of voltage. Constancy of frequency therefore and as accurate a determination of

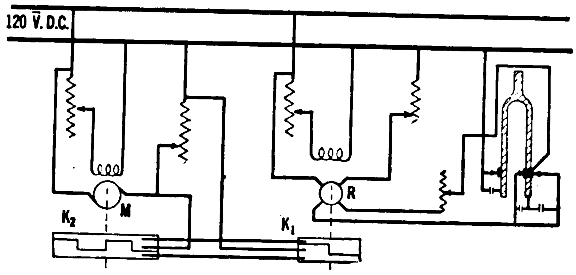

FIG. 6—CONTROL OF FREQUENCY BY TUNING FORK

its value as possible are highly essential to an accurate determination of the maximum voltage.

As regards constancy, the 5-kw. single-phase generator was driven by a continuous-current motor run as the only load on a large storage battery. This constant source of supply was further supplemented by an automatic speed control illustrated in Fig. 6. In this method the ultimate source of constant speed is an electrically operated tuning fork. A small rotary converter, R, of the same frequency as the tuning fork is driven from the direct-current end and is loaded with a resistance on the alternating-current end, the load circuit being taken through a pair of contacts on the tuning fork, contact being made once during each half wave. The time interval of contact by the tuning fork is a fraction of the whole alternating-current period. If the speed rises, contact is made at an instant when there is a greater electromotive force and current, thus resulting in a greater load on the converter. If the speed goes down, the conditions are reversed, consequently the tendency of the change of load is to maintain the speed of the converter constant. This tendency can be made greater or more positive by inserting resistance in the armature circuit of the continuous-current end of the converter.

The shaft of the small converter and that of the larger machine which is to be controlled are each supplied with a crown commutator, K_1 and K_2. The number of commutator segments for each is chosen so that by their speeds the frequencies of reversal of the two commutators are the same. The commutators are connected together electrically, as indicated in Fig. 6, in such a way as to short-circuit a small resistance in the armature circuit of the main driving motor for a greater or less period, according as the commutators depart more or less from the position of exact coincidence of phase. The machines automatically find such a relative commutator phase relation that an increase in speed decreases the duration of short circuit of the armature resistance, and vice versa, so that the average voltage on the motor armature is such as to more or less exactly maintain the speed in a constant relation to that in the small converter, which in its turn is maintained constant by the tuning fork. The introduction of the small converter is necessary, since the tuning fork contacts will not carry the large currents interrupted in the control of the considerably larger direct-current motor.

The use of the foregoing method prevented slow changes of speed due to temperature changes in the motor, or to variations of applied voltage, etc. Occasionally changes of this character were sufficiently great to overcome the regulating power of the tuning fork and the resulting upset in frequency was immediately indicated by the "beats" between the two frequencies detected by means of a pair of stroboscopic disks, one on each machine and through either of which the tuning fork might be viewed. In this way it was possible to tell at any instant by a glance whether the frequency was constant.

Observations taken with the stroboscopic disks indicate that by the above method the frequency was maintained constant at within 0.5 per cent. In this connection it is to be noted, however, that as read by the galvanometer, the charging current of the air condenser is read as an average value. Consequently, so long as the frequency is kept to an average constant value, momentary changes of frequency will not be registered in the galvanometer. This was borne out by the general character of the galvanometer reading, this reading being always absolutely stationary and not subject to any momentary variations which could be detected.

(*g*) *Value of Frequency.* Most of the measurements described in this paper were made at 60 cycles and this frequency is to be understood unless particular note is made of some other value. The frequency of the tuning fork was measured each day by bringing the small rotary converter into synchronism with the fork by the method described above and then taking the speed of the rotary by means of a "tachascope" or, combined revolution counter and stop watch. The speed of the rotary corresponding to 60 cycles for the alternating generator was 1800 rev. per min. The usual method of observation was to take the number of revolutions of the rotary within a period of three min-

utes, taking this observation three times and taking the mean of these for the determination of frequency. Table IV gives an example of the measurements which indicate that the average frequency was determined to within 0.04 per cent.

(*h*) *Capacity of Air Condenser*. As already stated, the air condenser was of concentric cylinder type. It had a continuous inside member and an outer member

TABLE IV.
MEASUREMENT OF FREQUENCY.

Time	Revolutions of control rotary		
3 min.	5400 + 4.5	5400 − 4	5400 − 6
3 min.	5400 − 1	5400 − 3	5400 − 2
3 min.	5400 + 3.5	5400 + 5	5400 + 2
Average..........	5400 + 2.3	5400 − 2	5400 − 2
Average frequency.....	60.02	59.97	59.98

consisting of a central section protected at each end with guard rings. A photograph is shown in Fig. 7. Both members were made from standard cast iron pipe. The surface of the inner member was turned off so as to have a uniform diameter and to be free from surface

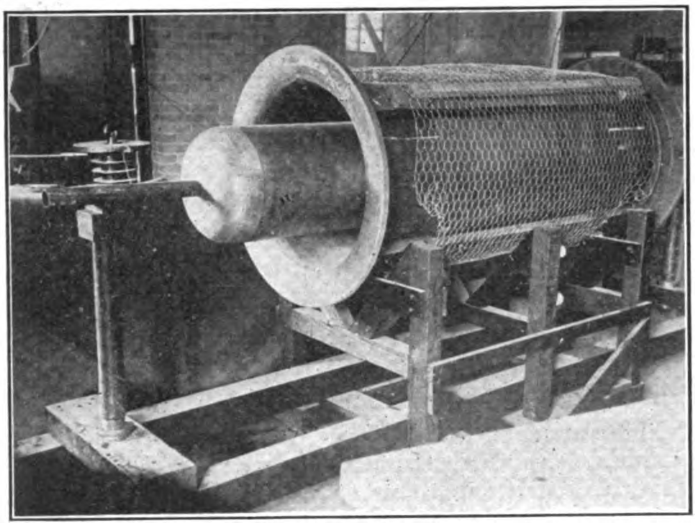

FIG. 7—AIR CONDENSER

irregularities. The ends were filled with rounded wooden plugs covered with tin foil and the whole inner member was supported by a 1½ in. pipe through central holes in these wooden plugs. The guard ring ends of the outer member consisted of straight sections on the outer ends of which were mounted standard flanges screwed on, the inside surfaces being turned off so as to provide a smooth flaring end to each guard ring.

The central or inner member was supported on dry oak posts boiled in paraffin. Sliding and screw adjustments at the top and bottom of these posts permitted accurate centering in relation to the outer member. The two guard ring ends were tied together by means of four stout oak pieces maintaining them in line. The central section of the outer member was supported on eight small plate glass insulators mounted in the four oak pieces mentioned. The whole was then supported in a wooden cradle, as indicated in Fig. 7.

Following are the principal dimensions of the air condenser:

Diameter of inner member......29.50 cm. (11.61 in.)
Average diameter of outer member..........................49.30 cm. (19.42 in.)
Length of central section of outer member....................76.20 cm. (30.00 in.)
Length of guard ring ends......30.5 cm. (12.00 in.)

The inside diameter of the outer member was not strictly uniform. It was measured in twelve places, the extreme variation being between 49.20 cm. and 49.51 cm. The calculated value of the capacity between the central section of the outer member and the inner member, based on the average diameter of the outer member given above, is 8.249×10^{-11} farads. In view of the uncertainty introduced by slight irregularities of this character, it was decided to measure the capacity.

The measurement of so small a value of capacity is a matter of considerable difficulty and requires much care. Maxwell's bridge method was used, following in general the experimental method of Rosa and Dorsey[11]. We were fortunate in being able to borrow

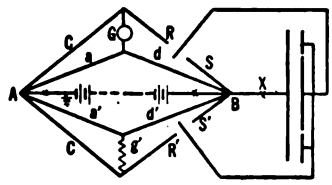

FIG. 8—MEASUREMENT OF CAPACITY OF AIR CONDENSER (8.28×10^{-11} FARADS)

from the National Bureau of Standards the special commutator constructed by them.

The diagram of the connections of this method is shown in Fig. 8. The principle is well-known and consists in replacing one of the resistances in a Wheatstone bridge with a condenser, and a suitable device for rapidly charging and discharging the condenser. In the arrangement shown in Fig. 8 the charging current only is used, the condenser being short-circuited in the alternate intervals. If, as in our case, the condenser has guard rings, it is necessary that they follow the same cycle of potential as the central section to be measured. This is accomplished by the double bridge shown in Fig. 8. R S and R' S' are contacts carried on the special form of rotating commutator constructed by Rosa and Dorsey for effecting the simultaneous charge and discharge of the central and guard ring members.

The bridge is balanced by varying the arms a and a' and when in proper adjustment corresponding arms in the two bridges must have identical values. The

value of the capacity between the inner member and the central section of the outer member is

$$C = \frac{a\,F}{n\,c\,d} \tag{5}$$

a, c and d are values of resistance; n is the number of charges of the condenser per second; and F is a correction factor depending on the relative values of the resistances, and differing but little from unity; in our work by about 3 points in 100,000.

The values used by us were as follows:

$$c = c' = 521{,}000 \text{ ohms}$$
$$d = d' = 50{,}000 \text{ ohms}$$
$$g = g' = 1{,}124 \text{ ohms}$$

The high resistances were of manganin made up of specially wound non-inductive units lent by the Bureau of Standards. The remaining resistances were of standard, high-grade, laboratory type, and all values as given were measured in terms of laboratory standards to 0.04 per cent.

For the determination of n, the number of charges per second, the commutator which had sixteen segments was geared directly to the small rotary converter controlled by a tuning fork by the method of Fig. 6, as already described. Two speeds differing by the factor 2 were possible with this arrangement, control of the machine speed by the fork being effective at either speed. Moreover, observation by means of the stroboscopic disk as to the constancy of the speed was also possible. The fork thus served for maintaining the frequency of charge and discharge at the average uniform value pertaining to either of two speeds. The value of this frequency, and thereby the value of n, was determined by a contact-making device on the commutator and a stop watch. The normal speed of the rotary was 1800 rev. per min. and this corresponded to the value of $n = 480$. The accuracy of the speed determination and so of the value of n was therefore within 0.04 per cent.

In measuring the capacity it was necessary to make a correction due to the capacity of the lead wires between the condenser and the bridge. This was done by measuring the capacity first with the condenser in and then with the connection to the central member of the condenser opened at the point X, Fig. 8. Two precautions have to be taken following this method; first, as to the insulation resistance of the capacity to be measured and the insulation resistance of the central section of the outer member to ground; and second, the capacity between the bridge wiring and the central member when the connection at X is opened.

With reference to the insulation resistances mentioned, it was found that in moist weather the values were relatively low, say of the order a few hundred megohms, doubtless owing to the rather large surfaces of support of the heavy parts. However, in clear dry weather the resistances were greater than one-half million megohms, a figure which reduces the possible error on this account to quite negligible proportions. These figures include the commutator insulation and were checked at each series of observations for the measurement of the capacity.

As to the possible error due to a charging current from the open contact at X through the capacity to the central member and thence to the outer member, this error was avoided by completely enclosing the projecting ends of the central member of the condenser by means of large cones made of galvanized sheet iron, the connection to the central member being carried through a small opening in one of the cone ends. The opening X was made at this place and under these circumstances the interior central member was entirely screened during the measurement for the correction due to the capacity of all the auxiliary wiring.

TABLE V.
MEASUREMENT OF CAPACITY OF AIR CONDENSER.

	Half speed $n = 240.2$, $n\,c\,d = 62.56 \times 10^{11}$, A positive		Full speed $n = 480.3$, $n\,c\,d = 125.12 \times 10^{11}$, A positive	
X	Left	Right	Left	Right
Closed	940			1851
Open	419	417	805	810
Closed	939	934	1839	1854
Open	419	417	805	814
Closed		934	1835	
Difference	520.5	517	1032	1040.5
Capacities	8.320	8.264	8.248	8.316
Mean	8.296×10^{-11}		8.282×10^{-11}	
X	A negative		A negative	
Closed		930		1867
Open	420	415	826	828
Closed	941	929	1864	1864
Open	420	415	826	828
Closed	942		1864	1858
Difference	521.5	514.5	1038	1035
Capacities	833.6	8.224	8.296	8.272
Mean	8.280×10^{-11}		8.289×10^{-11}	

Mean of means 8.286×10^{-11} farads.
Calculated value 8.262×10^{-11} farads.

The most difficult part of this measurement is the adjustment of the brushes on the commutator for simultaneous charge and discharge of the central section and the guard ring ends. This requires very careful study of the conditions of contact of the brushes on the commutator sections, so as to prevent mechanical vibration and to ensure a reasonable permanence

of a proper adjustment when once it is effected. Probably the best test of these conditions is by means of an auxiliary circuit through the brush contacts, indicating by means of a galvanometer the ratio of the running to the standstill deflections. By taking the two sets of brushes in turn singly and then in series, a quite accurate idea of the conditions is obtainable. Throughout the measurements of capacity, observations of this character were taken both before and after the capacity readings, thus ensuring satisfactory conditions. As an additional precaution in this direction a double set of readings was always taken, the duplicate contacts of the commutator being exchanged for the two readings between the central section of the condenser and the guard rings. Table V gives the readings which were selected as having been taken under the most favorable conditions, that is to say, those in which there was least difference between the two values of capacity corresponding to the exchange of the two sets of brush contacts.

The figures given in Table V are the values of the resistance "*a*" in ohms. The words "right and "left" refer to the particular set of commutator brushes used. It will be noted also that readings were taken for two speeds and for each speed a reading for a reversal of the polarity of the battery of the bridge. The value of the capacity in each case is calculated by means of Formula (**5**). The final average value of these readings is 8.286×10^{-11} farads. The calculated values based on independent measurements of the dimensions by each of the authors were 8.28×10^{-11} and 8.245×10^{-11} farads.

In computing the maximum value of voltage the measured value of the capacity, 8.286×10^{-11}, has been used.

(*i*) *Electrostatic Screening.* In view of the small value of the current to be measured, especial care had to be taken for the elimination of all electrostatic inductive effects between the high-tension circuit, the outer surface of the condenser, and the various measuring circuits in the ground connection of the condenser. With the sensitive galvanometer used it was found that the unscreened exposure of relatively small and distant portions of the wiring could introduce considerable error. It was necessary for the elimination of errors of this character to completely enclose in grounded casing all of the low-voltage measuring circuits of Fig. 1, including the various auxiliary circuits not shown; thus the kenotrons, the resistances, R_1, R_2 and R_3 and their various control circuits were enclosed in one sheet-iron box. The entire equipment of the observer's station, including the galvanometers for the measurement of the charging current and for the detection of corona and the various calibrating circuits were all enclosed in a small chamber completely surrounded with wire mesh. The condenser itself was surrounded with an outer screen of wire mesh. All connections between these various parts were likewise carried in metal conduit. All of the screening coverings described were connected together and to ground.

The test for completeness of electrostatic screening consisted in opening the high-voltage connection to the

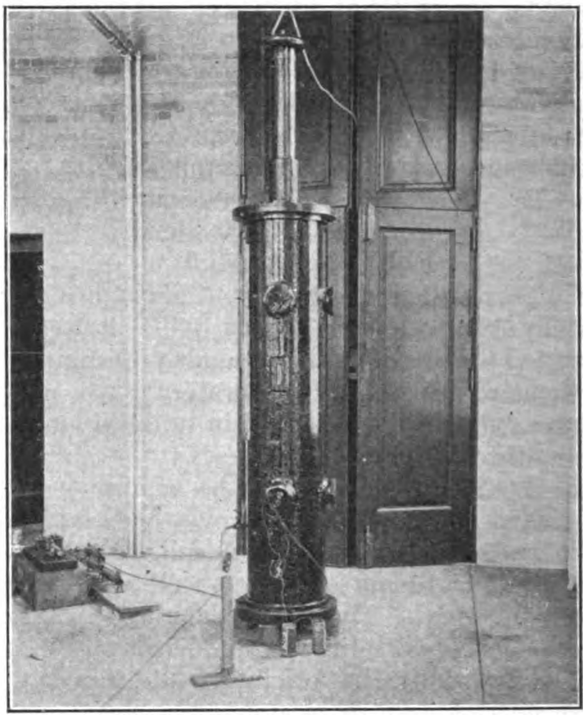

Fig. 9—Corona Voltmeter—200,000 Volts

central member of the air condenser at P, Fig. 3, applying the voltage, and observing the galvanometer in the method of connection of Fig. 3. In this observation the value of R_1 was 9900 ohms and is about five times the value used in the charging current measurements. The sensitivity of the galvanometer used was

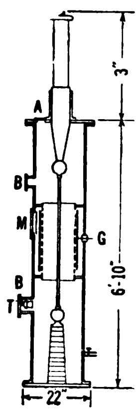

Fig. 10—Corona Voltmeter—200,000 Volts

1250 megohms and no deflection could be detected. The galvanometer could be read to 0.2 millimeter which, in accordance with the magnitude of the deflections corresponding to the charging currents measured, means that an error on account of electrostatic induction, if present, is less than 0.1 or 0.2 per cent.

III. 2. Detection of Corona

All of the corona observations on which the measurements are based were taken with the corona voltmeter shown in Fig. 9. A vertical section (not to scale) is shown in Fig. 10. The principal dimensions are,—height overall 9 ft. 10 in.; outside diameter 22 in.; diameter of grounded electrode cylinder 24.67 cm. (9.715 in.); length 60.95 cm. (24 in.). This cylinder was perforated over its whole surface with 0.952-cm. (0.375-in.) diameter holes on 1.27-cm. (0.5-in.) centers. The corona rods, 11 in number, of diameters ranging from 0.1038 to 1.2665 cm. were of tool steel polished and nickel-plated, and were all of the same length and equipped with similar threaded end fittings. A small opening A in the top cover permits easy insertion or removal of a rod, attachment of fittings to top and bottom insulators being made through two hand holes in the sides (see A, B, B, Fig. 10). These openings are closed with air-tight covers. The cover at A has a glass window permitting observation of visual corona. The locations of the thermometer M, the telephone, the connections T and G for telephone and galvanometer, and other auxiliaries are indicated in Fig. 10.

(*a*) *Visual Corona.* Attention was first drawn to the phenomenon of the high-voltage corona by the power loss between transmission lines. This was promptly found to be accompanied by the visual corona around the conductors. All of the early studies of corona formation, of which the most notable were those of Ryan, gaged the first presence of corona by visual means. The visual method, however, is neither convenient nor accurate. It necessitates working in a dark room and is subject to error, in that accurate observation depends upon the state of the eye as regards its recent usage, fatigue, etc.

Nevertheless, under carefully controlled conditions using long time intervals for eye rests, it is possible to secure consistent observations with the visual corona. In the earlier papers of one of the authors comparisons of corona voltages as between the visual and other methods have been recorded showing that they have identical values. In the present work observations of this character have been repeated in some of the auxiliary experiments and they show the identity of corona voltages as observed by the visual method and by the far more convenient and accurate galvanometer. The visual method has, however, not been used for the measurements, the telephone and galvanometer being far more accurate and convenient.

(*b*) *The Telephone as Detector.* The presence of corona may be detected by its sound even in an open space. If the corona conductor is surrounded by an outer casing, such as a cylinder forming the opposite conductor, the sound within this enclosing space is confined and intensified. It may be conveniently used as a detector of the first presence of corona by means either of a direct tube connection between the ear and the enclosing chamber, or by means of a telephone transmitter within the enclosing chamber and a receiver at the ear. The latter method is necessary if the air pressure is to be varied and so is used in the corona voltmeter.

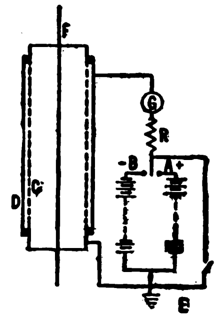

Fig. 11—The Galvanometer as Detector of Corona

A number of experiments have been recorded in earlier papers, showing the identical values of corona voltages as observed visually, with the telephone, and with the galvanometer method described below. During all of the present work the telephone and galvanometer have been used simultaneously and the work throughout makes it certain that either of these methods may be used for detecting the first presence of corona.

TABLE VI.
GALVANOMETER AND TELEPHONE AS DETECTORS OF CORONA.
0.314 cm. diameter rod.

Positive electrode		Negative electrode		Electrode zero potential	
T. C. volts	Deflection cm.	T. C. volts	Deflection cm.	T. C. volts	Deflection cm.
0	0.0	0	0.0	0	0
31.4	0.0	31.4	0.0	31.4	0
31.5*	0.0	31.5*	11.7	31.5*	1.4
31.7	0.0	31.6	16.7	32	5.1
31.8	0.0			33	7.3
31.9	0.06			34	8.7
32	0.1			35	9.1
32.1	0.18			36	8.4
32.2	0.58			37	6.3
32.5	1.08			38	3.6
33	5.9			39	0.1
34	19.8			40	− 3.9

*Telephone.

The present work, however, has revealed that the character of the note in the telephone is different under different conditions as regards the size of the corona conductor and the density of the air surrounding it. This feature has considerable value after slight experience in the operation of the corona voltmeter, as it gives the observer information as to the conditions under which he is working. As regards its bearing on the accuracy of the telephone as a method of telling

the first presence of corona, it is only necessary to note that the first uniform continuous note, whether it be faint and high or considerably louder and of lower tone, is to be taken as the signal of the presence of corona. The first type mentioned pertains to large wires at low pressure and the second to smaller wires and higher pressures.

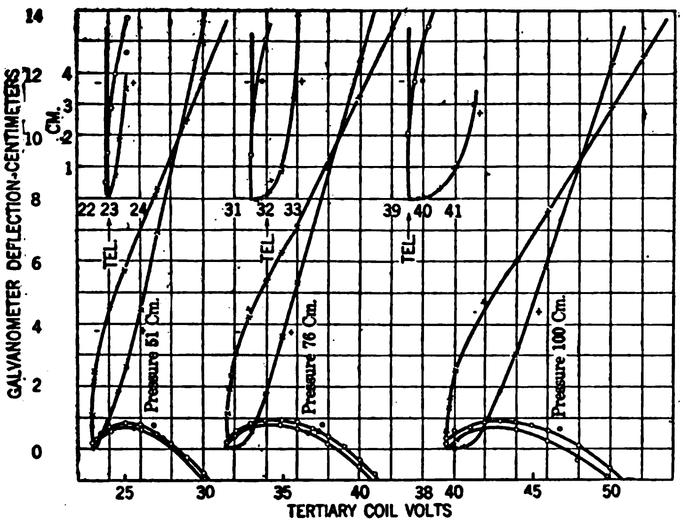

Fig. 12—Galvanometer as Detector of Corona—0.314-Cm. Diam. Rod

Irregularities or other surface imperfections of the corona rod can usually be detected in the telephone by a characteristic crackling note quite distinct from that of corona.

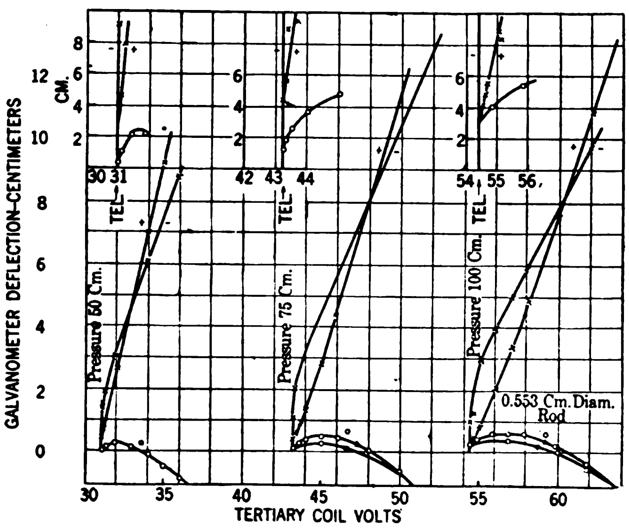

Fig. 13—Galvanometer as Detector of Corona—0.553-Cm. Diam. Rod

(c) *The Galvanometer as Detector.* The essential elements of the galvanometer method of detecting corona are shown in Fig. 11, in which C is the perforated cylinder in the corona voltmeter which is connected to ground and to one side of the voltage to be measured; D is a surrounding cylinder only slightly larger in diameter than C, from which it is carefully insulated. The remaining elements of the circuit are obvious from Figs. 1 and 10. When corona appears on the central rod F, the surrounding air is copiously ionized and this ionization extends through the perforations to the space between the cylinders C and D which thus becomes highly conducting, resulting in a deflection of the galvanometer G.

An extensive series of observations has been made with corona rods of various size and under different conditions as to temperature and pressure on the relation between the voltage on the corona rod F and the resulting galvanometer deflections. A characteristic series of observations are given in Table VI, and the corresponding curves are plotted in Figs. 12, 13 and 14. In connection with these observations it may be noted that the sensitivity of the undamped galvanometer was 1280 megohms, and when critically damped with a shunt of 3400 ohms the sensitivity

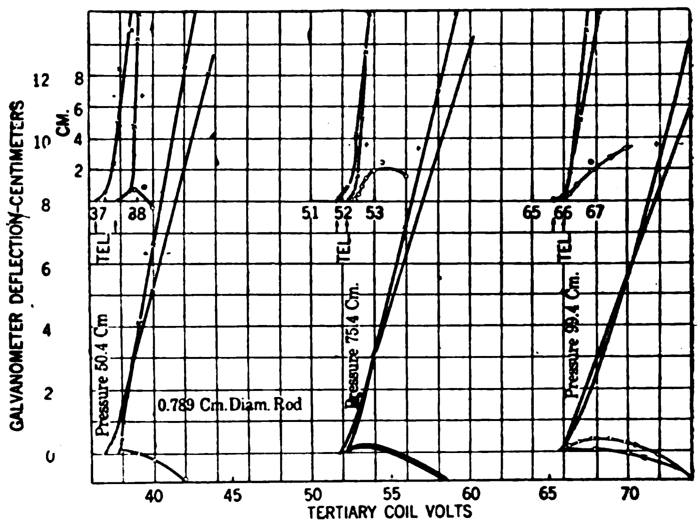

Fig. 14—Galvanometer as Detector of Corona—0.789-Cm. Diam. Rod

was 428 megohms. The resistance R was 50,000 ohms and the battery $\pm$ 115 volts. From the dimensions of the corona voltmeter already given, the length of the cylinder D was 60.95 cm., its diameter 24.67 cm., and its space separation from the cylinder C 0.317 cm. From these constants and from the observations the resistance of the space between C and D when in the initial conducting condition corresponding to the start of corona is about 1600 megohms.

Figs. 12, 13 and 14, pertaining to three different sizes of corona rod, are plotted with galvanometer deflections in centimeters as ordinates and transformer tertiary coil volts as abscissas. Each contains three sets of curves taken at different values of air density. The upper smaller curves are taken with the value of galvanometer sensitivity used throughout the voltage measurements. The larger curves are taken with galvanometer sensitivity reduced to 1/10 in order to extend the curves. Three curves were taken at each pressure, one each for the electrode D

of Fig. 11 at 115 volts positive potential, one at 115 volts negative potential, and one at ground potential. The value of voltage at which the telephone is first heard is also indicated. It is to be noted that in all of these curves negative potential on the electrode D is best for the detection of the first presence of corona in that the curve rises most sharply. This is especially noticeable with small rods. With larger rods the advantage of negative over positive potential holds at low pressure, but tends to disappear at high pressures.

With larger rods at low pressures where the negative electrode should be used for first detection of corona, the telephone gives a pure high note of relatively faint volume within the interval of voltage between the curves of negative and positive electrodes, the full volume of sound appearing when the latter curve begins. At high pressures the curves come together; and with either positive or negative electrode the first corona is accompanied by a full sound in the telephone. With the smaller rods, although there is also a lag of the rise of the curve of positive electrode behind that of negative electrode, the faint initial high tone in the telephone is absent and except at very low pressures there is no marked variation in the telephone note, this note being clear and full with the first appearance of corona with negative electrode.

Considering the foregoing, therefore, from the standpoint of accuracy of determination of the first appearance of corona, negative potential should be used on the electrode D in all cases. Conditions of observation with both telephone and galvanometer are better at values of air density above that of normal atmosphere, rather than below, if large rods are used. Consequently, for reading low voltages better conditions are obtained by using a small rod rather than by using a large rod with reduced air density.

The difference in shape of the curves of positive and negative electrode has been noted in an earlier paper. The greater sensitivity of the negative electrode is obviously due to the fact that corona formation or ionization of the air occurs first due to the motion of the negative electrons. The acceleration of the electron is greatest when it is moving toward the positively charged corona conductor. Under these circumstances the positive ions, as products of the process of ionization, would be repelled and would therefore give maximum current in the galvanometer circuit of Fig. 11 when the electrode D is negative. The exact shape of the curves probably depends on the wave form of voltage, moisture content of the air, and possibly on the frequency. It is only the initial slope of the most sensitive of these curves that is of importance in the detection of corona; their shape above the region of starting is of no present interest. It may be noted in passing, however, that it is possible to eliminate the voltage for the electrode D entirely and still observe the beginning of corona, although at a considerably lessened sensitivity. The curves showing the galvanometer deflection when the electrode D is at ground potential are seen to show reversal of galvanometer deflection at the voltage at which the curves of positive and negative electrodes intersect.

With reference to the actual degree of accuracy to which the beginning of corona could be observed, it will be noted from Fig. 12 that the galvanometer deflection begins and increases so sharply as to be practically instantaneous. Thus, for example, in Table VI and Fig. 12 the galvanometer deflection increases from 0 to 11.7 cm. within the voltage interval 31.4 to 31.5, the telephone coming in sharply at the same point. This indicates an accuracy of a very small fraction of 1 per cent. With the larger rod in Fig. 14 at high pressure we have a deflection of 1.4 cm. within the voltage interval 65.9 to 66. At low pressures the deflection is 2.4 cm. within the voltage interval 36.7 to 37.2. From this it will be seen that the sensitivity of corona detection is still quite high even under the unfavorable conditions of large rod at low pressure.

Throughout the observations the telephone and the galvanometer were read simultaneously, each checking the other. If an appreciable galvanometer deflection occurred without a corresponding clear telephone indication, or vice versa, an explanation could usually be found in a local spark or other surface impurity on the rod. We believe, in view of the foregoing that throughout the work the accuracy with which the beginning of corona has been read is better than 1/10 of 1 per cent. In this connection it may be pointed out that the initial flat portion or low rate of rise of the negative curves with large wires can only be detected by use of a very sensitive instrument. These initial portions are probably due to slight surface imperfections rather than to full corona. This is borne out by the fact that the full telephone note comes out at a point corresponding to the steep portion of the curve. With an instrument of lower sensitivity, such as would normally be used with the corona voltmeter, these initial portions of the curve cannot be detected and the instrument takes an initial sharp deflection accompanied by the simultaneous telephone note.

III. 3 Measurement of Air Density

The relative air density δ as given in Formula (3) is

$$\delta = \frac{3.92 \times p}{273 + t} \qquad (3)$$

p being the absolute pressure in centimeters of mercury, and t the temperature in degrees centigrade. Thus δ has the value 1 at 76 cm. mercury and 25 deg. centigrade.

(*a*) *Pressure.* In the experiments the pressure was read on an open mercury manometer, (see Fig. 10), the accuracy of observation therefore being to about 0.2

millimeter. The usual correction for temperature was applied. All of the observations leading to the precision Formulas (7) and (8) for the electric strength of air were taken within the range of pressures 25 cm. and 139 cm. absolute, all of which was covered by the mercury manometer. A number of observations studying the performance of the corona voltmeter at higher pressures were made with a standard direct-reading gage by Schaeffer & Budenberg, calibrated within their common range in terms of the mercury manometer.

At the highest and the lowest pressures slight leaks in the outer casing of the voltmeter were detected. These leaks were, however, quite slow and pressure readings were taken at the beginning and end of each series of voltage readings. The average value of pressure within the interval was usually taken in these cases and an inspection of Table VII indicates that the error on this account was negligible. In calculating δ, p is the absolute pressure in centimeters of mercury. The open mercury manometer reads pressure with relation to the atmosphere. Atmospheric pressure was determined from the laboratory standard barometer with the usual correction for temperature.

(*b*) *Temperature.* The temperature within the volt-

TABLE VII.

CORONA VOLTAGE READINGS.

			Press. Guage		Corr. Abs. Press.	Voltage Galvanometer							Ter. Coil Volts
						At start of Corona			Calibration				
Freq.	Bar. Press.	Temp.	Left	Right		Left	Right	Mean	Left	Right	Volts 499 ohms	Milamp. per div.	
0.4765 cm. diam. rod													
60.03	76.56	18.9	72.30	8.60		10.22	10.30	10.26	10.26	10.29	0.3890		65.9
						10.23	10.30	10.26					65.95
					139.74							0.07590	
						10.22	10.30	10.26					65.95
		19.0	72.00	8.90		10.22	10.30	10.26	10.23	10.30	0.3891		65.95
60.04	76.12	19.8				6.22	6.23	6.22	6.19	6.21	0.2348		40.2
						6.19	6.23	6.21					40.1
					76.12							0.07591	
						6.19	6.22	6.20					40.1
		20				6.19	6.22	6.20	6.18	6.22	0.2348		40.05
60.03	76.50	18.8	19.97	60.48		3.46	3.48	3.47	3.42	3.44	0.1308		22.5
						3.47	3.49	3.48					22.2
					36.25							0.07642	
						3.48	3.49	3.48					22.3
		18.7	20.07	60.33		3.48	3.50	3.49	3.42	3.44	0.1308		22.4
0.7109 cm. diam. rod													
60.03	76.02	20.8	60.30	19.85		11.01	11.09	11.05	11.01	11.10	0.4189		70.9
						11.01	11.08	11.04					70.95
					116.13							0.07584	
						11.01	11.10	11.05					70.95
		20.8	60.12	20.05		11.00	11.09	11.04	11.01	11.10	0.4189		70.95
60.11	75.97	21.7	30.02	50.17		6.08	6.12	6.10	6.01	6.03	0.22785		39.05
						6.08	6.11	6.095					39.05
					55.98							0.07585	
						6.08	6.11	6.095					39.1
		21.7	30.08	50.08		6.08	6.12	6.10	6.00	6.04	0.22785		39.1
60.03	75.07	21.7	20.35	60.10		4.17	4.29	4.23	4.18	4.30	0.1605		27.1
					35.60	4.18	4.29	4.235					27.1
												0.07588	
						4.19	4.3	4.245					27.3
		21.7	20.49	60.00		4.19	4.32	4.255	4.18	4.30	0.1605		27.4

meter casing was read on an ordinary laboratory centigrade thermometer hung within the casing near its wall and so that it could be viewed through a small glass window. The thermometer could be read to within about 0.2 degree. From an inspection of the value of δ this indicates that the absolute temperature was read to within less than 1/10 per cent.

The determination of the temperature in this way assumes that the temperature of the air at the surafce of the corona rod is the same as that near the outer wall of the voltmeter. There is an obvious possibility of error here, so the matter was investigated experimentally by comparing the thermometer mentioned above with another hung immediately adjacent to the corona rod and viewed by telescope through another glass window. The curves of Fig. 15 show the difference in temperature between these two thermometers resulting from rapid expansion and compression of the air within the voltmeter. They indicate that on compression from atmosphere to 30 cm. above atmosphere there is a resulting difference of temperature of about 1 deg. and on expansion of approximately ½ deg. between the two thermometers. In the former case the two thermometers reached the same temperature within five or six minutes and within a shorter interval in the latter case. In the observations no such sharp changes of pressure occurred, the common maximum change being about 10 cm. In all cases, however, sufficient time was allowed to ensure that the observed temperature was sensibly the same as that near the corona rod.

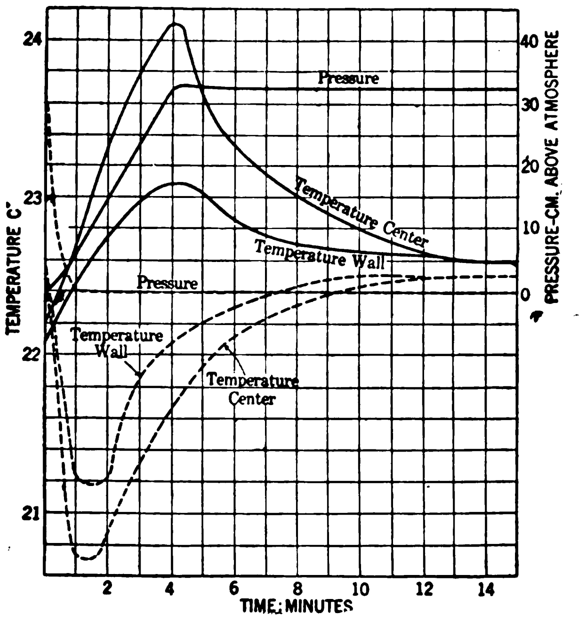

Fig. 15—Temperature at Surface of Corona Rod

IV. Experimental Observations

Many hundreds of observations were taken with eleven different sizes of corona rod of diameters as follows: 1.266, 0.955, 0.790, 0.710, 0.654, 0.5536, 0.4765, 0.3142, 0.2060, 0.1197, 0.1038 cm. The figures for the diameters given in the tables and computations are the average values taken from 20 micrometer measurements on each rod. Except in the cases of the smallest rods, the maximum variations from the mean diameters as given were quite small, that is, in the neighborhood of 0.2 or 0.3 per cent. The rods were all of tool steel and nickel-plated after polishing, this material and treatment yielding the most accurate cylindrical shape and smoothest surface that we have found. The extremes of absolute pressure reached in the precision determinations were 25 cm. and 139 cm. of mercury, although not all the rods were carried through the entire range.

The usual sequence in taking observations was as follows: Adjust frequency control and read its value; set pressure in corona voltmeter to desired value; adjust filament current and kenotron circuit for zero current in the closed kenotron circuit; read temperature and pressure in voltmeter; raise voltage slowly until corona begins, as indicated by galvanometer and telephone; read value of charging current of condenser by galvanometer.

One observer took the temperature and pressure and read the charging current galvanometer. A second observer, who raised the voltage, was equipped with telephone head-piece and read the galvanometer indicating the beginning of corona. This observer also took a reading of an ordinary direct-reading voltmeter connected to the tertiary coil of the high-tension transformer. This last reading was useful as a check of the constancy of circuit conditions and for rough comparisons, but its readings were not used in any computations. At the instant that the presence of corona was detected by galvanometer and telephone the slow elevation of voltage would be stopped and the first observer would take the reading of the charging current galvanometer. Obviously the voltage elevation could be made as slow as desired and frequent check readings were taken which do not appear in the record. The degree of constancy of the corona voltage is discussed in the following paragraph. After each series of observations the charging current galvanometer was calibrated at a deflection approximately equal to that of the observation.

Table VII gives six typical sets of readings of the principal data, these sets being selected at random from the observation sheets. The first six columns give the frequency, temperature and pressure, leading to the corrected absolute pressure in Column 6. Columns 7 and 8 give the right and left readings of the galvanometer measuring the condenser charging current. It will be noted that there are four pairs of such readings for each value of pressure. Between the readings of each pair and between each of the pairs the voltage was lowered below corona value and raised again. The readings of these columns therefore are a good indication as to the accuracy with which corona formation repeats itself.

Since the beginning of corona is indicated by the telephone and by a sudden sharp deflection of the galvanometer rather than by the magnitude of the deflection of the latter, this latter reading was not recorded. (See however Figs. 12, 13 and 14.) A direct relative indication of the alternating voltages at which successive coronas start is available, however, in the tertiary coil voltmeter and the readings of this instrument are given in the last column of Table VII.

Referring to the readings of the pressure, it will be noted that there is usually a difference in the net readings of the mercury manometer at the beginning and at the end of each series of four pairs of corona readings. These differences are due to slight leakage of the voltmeter casing and are therefore greatest for the highest and lowest absolute pressures. The differences are never very great and when they occur they are followed by a corresponding change in the corona voltage as indicated by the condenser charging current. Therefore in taking for each set of readings the average value of the pressure and the average value of the galvanometer reading no appreciable error is introduced.

Three sets of auxiliary observations should be recorded here bearing, respectively, on the perforation of the grounded cylinder, the influence of frequency and the permanence of the surface of the corona forming rod.

As regards the holes in the grounded cylinder, a number of observations from time to time have shown that these perforations have no effect on the value of the corona-forming voltage; for example, in the paper "The Electric Strength of Air.—III"[13] a number of experiments were conducted with an outer cylinder made of wire mesh of a quite wide opening. The values of corona voltage observed in this case were sensibly the same as those obtained with cylinders with continuous walls. Further, numerous readings taken with outer cylinders having continuous walls have shown that the voltages at which visual corona appears are in accord with those observed in the corona voltmeter. In order, however, to make a direct test of this question, two series of observations of visual corona voltage were taken, using in the two cases outer cylinders cut from the same length of brass tubing, one piece being perforated and the other not perforated.

The two tubes were each 9.5-cm. inside diameter and of length 24 cm. One was perforated with 0.27-cm. diameter holes drilled as closely as possible to each other and in a number of cases being actually tangent to each other. A clean rod 0.315 cm. in diameter was centered in each of these tubes in turn and visual corona observations taken with a rested eye in a darkened room. The corona voltages as measured on the transformer tertiary coil in the two cases were: with perforated cylinder 23.5, 23.4, 23.4; with unperforated cylinder 23.4, 23.5, 23.6, 23.5, 23.5. There appears therefore no reason to question that the perforations in the grounded cylinder have no effect on the value of corona-forming voltage.

As regards the influence of frequency on corona-forming voltage, in the paper "The Electric Strength of Air.—II",[14] experiments were described which indicated a slight lowering of corona voltage with increasing frequency between the range 10 and 100 cycles. Subsequently Whitehead and Gorton[8] have extended the range of frequency up to 3000 cycles and have shown that within the range 500 to 3000 cycles there is practically no influence of the frequency on the corona-forming voltage. They noted, however, that the value of corona voltage within this range was from 3 to 4 per cent lower than at 60 cycles. F. W. Peek records that within the range of commercial values the frequency has no influence on corona-forming voltage.

TABLE VIII.
INFLUENCE OF FREQUENCY.

Frequency cycles per second	Values of $\frac{E}{\delta}$ at $\frac{1}{\sqrt{\delta r}} = 2.03$	Aver.
20	50.41, 50.50	50.45
40	50.25, 50.25, 50.39, 50.5	50.35
60	49.95, 50.07, 50.13	50.05
90	49.24	49.24

Having at hand the accurate method of measurement already described, a series of observations was taken on the influence of frequency between the values 20 and 90 cycles. The readings were taken on a rod 0.48 cm. in diameter and at atmospheric pressure. Several readings at each frequency were taken and all were reduced to the same value of $\frac{1}{\sqrt{\delta r}}$. The corresponding values of E/δ are given in Table VIII.

The above figures indicate that there is a small influence of frequency on corona-forming voltage within the range 20 to 90 cycles. For example, the corona-forming voltage at 25 cycles is shown to be about 0.8 per cent higher than at 60 cycles. All of the other observations of this paper were taken at 60 cycles and therefore the laws of corona formation, as discussed below, pertain to that frequency.

As regards the permanence of the surface of the corona-forming rod, experiments have shown that a practically indefinite number of corona observations may be taken without deterioration of the surface of the nickel-plated steel rods used. These experiments consisted in maintaining corona on a rod for a long period of time, interrupting it at regular intervals and taking the corona-forming voltage. One of several such tests consisted in maintaining a 0.476-cm. diam. rod at a voltage 2.5 per cent above the corona-forming

value for one hour, and taking the corona-forming voltage six times during the interval. At start the corona-forming voltage as indicated at the tertiary coil terminals was 40.1; at successive intervals through the hour the values were 40.05, 40.05, 40.05, 40.15, 40.2, 40.1.

If the voltage is carried higher, increasing the volume of corona discharge, the surface will ultimately develop local spark points, leading to local sparks at voltages lower than corona-forming values. Normally, however, with an initially clean rod and dust-free air inside the voltmeter, the surface of the rods in the corona voltmeter shows a most satisfactory degree of permanence.

TABLE IX.
COMPUTED VALUES FOR LAW OF CORONA.

Rad. r cm.	Temp. t deg. cent.	Press. p cm.	δ	Kv. max.	Surf. int. E kv/cm max.	$\frac{E}{\delta}$	$\frac{1}{\sqrt{\delta r}}$	$\frac{E}{\delta}$ calc.	Diff. per cent.
0.2383	18.0	46.92	0.6322	32.51	34.57	54.69	2.577	55.02	−0.60
"	18.0	47.20	0.6360	32.71	34.79	54.71	2.569	54.95	−0.44
"	18.1	47.37	0.6381	33.00	36.00	55.01	2.565	54.92	+0.16
"	18.7	35.97	0.4835	26.42	28.09	58.11	2.946	58.17	−0.10
"	18.75	36.25	0.4872	26.73	28.42	58.35	2.935	58.08	+0.47
"	20.3	26.65	0.3563	20.61	22.14	62.16	3.432	62.33	−0.27
"	20.5	27.06	0.3615	21.06	22.39	61.96	3.408	62.13	−0.27
0.1571	22.4	115.29	1.5301	52.24	76.21	49.80	2.040	50.11	−0.62
"	22.3	114.76	1.5238	52.20	76.15	49.97	2.044	50.15	−0.36
"	22.2	114.32	1.5185	52.09	75.99	50.04	2.048	50.19	−0.30
"	22.8	96.10	1.2739	45.00	65.65	51.53	2.235	52.05	−1.00
"	22.8	95.88	1.2710	45.04	65.69	51.69	2.238	52.08	−0.75
"	22.7	95.70	1.2690	45.05	65.72	51.78	2.240	52.09	−0.60
"	21.85	76.00	1.0107	37.37	54.51	53.94	2.510	54.45	−0.90
"	22.0	75.98	1.0099	37.54	54.66	54.23	2.511	54.46	−0.42
"	22.1	75.95	1.0092	37.54	54.66	54.27	2.512	54.46	−0.35
"	22.9	55.20	0.7315	28.98	42.28	57.80	2.950	58.21	−0.71
"	23.05	55.39	0.7336	29.17	42.35	58.00	2.946	58.27	−0.29
"	23.2	55.50	0.7347	29.24	42.66	58.06	2.944	58.25	−0.15
"	23.4	45.19	0.5978	24.89	36.31	60.74	3.263	60.90	−0.26
"	23.45	45.38	0.6002	25.03	36.51	60.83	3.257	60.84	−0.02
"	23.4	45.48	0.6016	25.04	36.52	60.70	3.253	60.81	−0.02
"	18.2	35.66	0.4802	21.15	30.86	64.26	3.641	64.13	+0.22
"	18.3	36.19	0.4871	21.42	31.25	64.14	3.615	63.91	+0.38
"	18.3	36.33	0.4890	21.46	31.30	64.01	3.608	63.85	+0.27
0.1030	26.0	115.48	1.5144	40.88	82.94	54.78	2.532	54.64	+0.26
"	26.0	115.01	1.5082	40.91	82.98	55.03	2.537	54.68	+0.64
"	26.0	114.68	1.5039	40.75	82.75	55.03	2.541	54.71	+0.59
"	20.6	114.80	1.5331	40.85	82.86	54.05	2.517	54.51	−0.85
"	20.75	113.97	1.5213	40.86	82.89	54.49	2.526	54.59	−0.18
"	20.8	113.70	1.5174	40.86	82.89	54.63	2.530	54.61	+0.04
"	26.7	96.05	1.2566	35.25	71.52	56.90	2.780	56.75	+0.26
"	26.6	95.77	1.2534	35.26	71.55	57.07	2.783	56.78	+0.51
"	26.6	95.62	1.2514	35.25	71.52	57.14	2.785	56.80	+0.60
"	19.9	76.05	1.0181	29.88	60.62	59.54	3.088	59.40	+0.24
"	20.0	76.03	1.0174	29.97	60.80	59.76	3.089	59.41	+0.59
"	20.0	76.00	1.0170	30.00	60.86	59.85	3.090	59.41	+0.74

V. Summary of Observations

From the complete data of which Table VII is a small portion, the values of the relative density δ are computed from Formula (3). The charging current galvanometer is calibrated directly in terms of current in the resistances R_1 and R_2 of Fig. 1. As already described, the readings of this galvanometer then lead through Formula (4) to the crest value of alternating voltage. From this value and the dimensions of the rod and the inner cylinder of the corona voltmeter, the critical or corona-forming electric intensity in kilovolts per centimeter at the surface of the conductor is readily computed. Some of these steps are given

TABLE X.

No.	Rad. cm.	$\frac{1}{\sqrt{\delta r}}$	$\frac{E}{\delta}$ obs.	$\frac{E}{\delta}$ calc.	Per cent discrep.
1	0.633	1.253	42.38	42.29	+0.21
5	"	1.386	43.71	43.61	+0.23
2	0.477	1.282	42.56	42.58	−0.05
4	"	1.353	43.02	43.28	−0.6
6	"	1.43	43.92	44.05	−0.3
7	"	1.431	44.20	44.06	+0.32
10	"	1.530	44.99	45.04	−0.11
12	"	1.661	46.28	46.34	−0.13
15	"	1.852	48.22	48.24	−0.04
16	"	1.870	48.57	48.42	+0.31
	"	2.117	50.79	50.88	−0.18
20	"	2.493	54.1	54.29	−0.35
3	0.355	1.349	43.24	43.24	0.0
8	"	1.480	44.60	44.55	+0.11
13	"	1.667	46.58	46.40	+0.39
	"	1.944	49.41	49.15	+0.53
19	"	2.418	54.01	53.66	+0.65
18	"	2.379	53.49	53.32	+0.32
9	0.238	1.503	44.55	44.78	−0.51
11	"	1.653	46.28	46.26	+0.04
14	"	1.798	47.70	47.70	0.0
	"	2.035	49.94	50.05	−0.22
	"	2.045	49.91	50.15	−0.48
	"	2.194	51.31	50.64	−0.65
17	"	2.375	53.07	53.29	−0.41
24	"	2.570	54.79	54.95	−0.29
26	"	2.941	58.22	58.11	+0.19
30	"	3.413	62.06	62.16	−0.16
	0.157	2.044	49.94	50.15	−0.42
	"	2.238	51.67	52.08	−0.79
21	"	2.511	54.15	54.45	−0.55
27	"	2.946	57.95	58.17	−0.38
29	"	3.257	60.76	60.84	−0.13
33	"	3.62	64.14	63.94	+0.31
23	0.103	2.537	54.95	54.68	+0.49
22	"	2.524	54.39	54.56	−0.31
25	"	2.783	57.04	56.78	+0.46
28	"	3.089	59.72	59.40	+0.54
32	"	3.610	64.25	63.87	+0.6
35	"	4.024	67.38	67.40	−0.03
38	"	4.562	72.21	72.00	+0.29
36	0.0598	4.041	67.99	67.54	+0.67
39	"	4.716	73.33	73.31	+0.03
41	"	5.22	77.48	77.63	−0.19
43	"	5.98	83.42	84.16	−0.88
31	0.0519	3.53	63.77	63.24	+0.84
34	"	3.865	66.57	66.04	+0.81
37	"	4.356	70.23	70.24	−0.01
40	"	5.097	76.46	76.58	−0.16
42	"	5.529	79.93	80.28	−0.44
44	"	6.254	85.60	86.47	−1.01

in Table VII and the more important ones are collected in Table IX.

Table IX shows about one-fourth of the total number of derived values for computing the law of corona. The summary of all these values is given in Table X. Each reading of voltage in Table IX corresponds to four pairs of right and left galvanometer readings at each pressure, as set forth in Table VII. It will be noted that on the average Table IX presents three sets of readings for each value of pressure. This means that for each pressure there are 12 observations of corona forming voltage. Table IX also includes both observed and computed values of $\frac{E}{\delta}$ and $\frac{1}{\sqrt{\delta\, r}}$, the latter based on the law of corona deduced from all the observations as set forth in the following section.

VI. The Law of Corona

As the work proceeded the values of $\frac{E}{\delta}$ and $\frac{1}{\sqrt{\delta\, r}}$ were plotted. It was found that the resulting curve was a straight line, in accordance with Formula (1), for the larger values of $\frac{1}{\sqrt{\delta\, r}}$. However, on extending the study to larger corona rods, and especially at the higher pressures, it was found that the points departed from the straight line indicated for smaller rods and lower pressures. This fact at first was quite disturbing as it suggested either a departure from the simple law of Formula (1) or the presence of some error in method or observation. Many readings were repeated but resulted only in confirming the earlier ones.

Further study and investigation of the foregoing interesting results led to the work of Whitehead and Brown[6] on "The Corona at Continuous Voltages," which shows that while both the positive and negative corona obey a law of the form of Formula (1), yet the constants A and B are different in the two cases. This means that if the law for each case is put into the form of the linear relation between $\frac{E}{\delta}$ and $\frac{1}{\sqrt{\delta\, r}}$ the two lines will intersect and that below the point of intersection negative corona appears first, while above the point of intersection positive corona appears first.

Extending the foregoing to corona formation at alternating voltage, we should find, if we plot between $\frac{E}{\delta}$ and $\frac{1}{\sqrt{\delta\, r}}$ that below the value $\frac{1}{\sqrt{\delta\, r}} = 2.25$, representing the intersection of the positive and negative corona curves, the alternating corona should obey the same law as the negative continuous corona and that above that value it should obey the law found for positive corona. This is exactly the result that we have found and it therefore constitutes a necessary, and in fact important, modification of the law of corona.

The foregoing conclusions are immediately obvious if all of the observations are plotted, and as the results are very consistent throughout, a quite close approximation to the exact values of the constants of Formula (1) is possible by this graphical method. However, it is obviously better to derive the values of these constants from the figures themselves, and for this purpose the "Sigma-Delta" method[12] for evaluating the constants, has been used.

If we attempt to apply the Sigma-Delta method to the entire set of observations, a part of which are given in Table IX, it becomes very laborious indeed. It appeared to us, therefore, that this could be avoided by a still further averaging of the results for one pressure corresponding to each of the groups of readings in Table IX, this averaging being done on the values of $\frac{E}{\delta}$ and $\frac{1}{\sqrt{\delta\, r}}$. There being a linear relation between these two quantities, no error is thereby introduced. In this way the values of Table X are reached. The first column of Table X gives the sequence numbers as used in the Sigma Delta method; the second and third columns the mean values of $\frac{1}{\sqrt{\delta\, r}}$ and $\frac{E}{\delta}$; the fourth column the calculated value of $\frac{E}{\delta}$ as derived from the Sigma-Delta method; and the fifth column the error as between observed and calculated values of $\frac{E}{\delta}$ expressed in per cent.

In applying the Sigma-Delta method to the figures of Table X it was thought best, in view of the uncertainty as to the exact point of intersection of the two straight lines referred to above, to omit the points in the immediate neighborhood of this point of intersection. Consequently the points were plotted, as shown in Fig. 16, and the approximate position of the point of intersection of the two lines thus determined roughly. This being done, the readings corresponding to values of $\frac{1}{\sqrt{\delta\, r}}$ between 1.9 and 2.3 were omitted from the computations for the reason mentioned. In this way the equation of the line below the point of intersection was determined from the first sixteen readings of Table X, comprising the interval 1.253 to 1.870, for $\frac{1}{\sqrt{\delta\, r}}$. There are twenty-eight readings above the point of intersection comprising values from 2.375 to

6.254 for $\frac{1}{\sqrt{\delta\, r}}$. These were used for determining the equation of the line above the point of intersection. The results of the computation give the following formulas:

For values of $\frac{1}{\sqrt{\delta\, r}}$ below 2.295 and in this range range negative corona appears first:

$$\frac{E}{\delta} = 29.87 + \frac{9.918}{\sqrt{\delta\, r}} \tag{7}$$

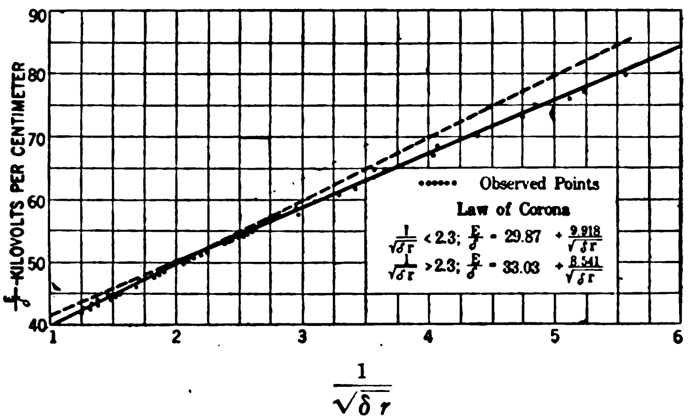

Fig. 16—The Law of Corona

For values of $\frac{1}{\sqrt{\delta\, r}}$ above 2.295 and in this range positive corona appears first:

$$\frac{E}{\delta} = 33.03 + \frac{8.541}{\sqrt{\delta\, r}} \tag{8}$$

The point of intersection of the two lines is $\frac{1}{\sqrt{\delta\, r}}$ = 2.295 corresponding to a value of $\frac{E}{\delta}$ = 52.62.

It is interesting to note in connection with Fig. 16 that observations on two of the rods used (0.238-cm. and 0.157-cm. radii) give several points each on both sides of the point of intersection of the two lines.

The extension of the observations in the direction of larger values of $\frac{1}{\sqrt{\delta\, r}}$ was readily accomplished by using smaller rods and lower pressures. The extreme values in this direction were reached in using a 0.0519-cm. diameter rod and an absolute pressure of 36 cm. of mercury giving the value 6.28 for $\frac{1}{\sqrt{\delta\, r}}$.

In the opposite direction, *i. e.*, smaller values of $\frac{1}{\sqrt{\delta\, r}}$ there is also a wide range possible in increasing the pressure and using larger rods. Our largest rod was 0.633-cm. radius and our greatest pressure about about 135-cm. mercury, giving 1.25 for $\frac{1}{\sqrt{\delta\, r}}$. As indicated elsewhere, larger rods are not desirable, but obviously much higher pressures can be used. Our limit in this direction was found in the break-down voltage of the air condenser, precluding precision measurements below 1.25 for $\frac{1}{\sqrt{\delta\, r}}$. However, we have made a number of observations of the performance of the corona voltmeter at higher pressures, with the precision voltage measurement omitted, and have found nothing to suggest a departure from the simple linear relation indicated in Formula (7) and Fig. 16.

VII. Advantages of the Corona Voltmeter as a Standard

The law expressed in Formulas (7) and (8) constitutes a definite standard over a wide range of voltage.

The range has been tested by precision measurements up to the neighborhood of 150,000 volts and with every evidence that the law continues beyond that value. The only quantities which enter are the radius of the corona rod, the radius of the outer cylinder, and the density of atmospheric air. This is equivalent to saying that the calibration of the corona voltmeter depends only on its physical dimensions.

As regards its availability in practical measurements, a workable corona voltmeter may be set up in practically any laboratory with very little trouble. A straight clean wire stretched on the axis of a surrounding metal cylinder will give very reliable indications in a darkened room with a visual observation of corona formation. With little additional trouble a galvanometer may be used as corona indicator. A considerable although not a continuous, range may be had by using corona wires of different diameters.

The construction of the complete corona voltmeter itself, moreover, is a relatively simple and inexpensive matter. Up to 100,000 volts it may be readily constructed in any well-equipped laboratory and for higher ranges offers no serious difficulties. With the complete instrument a wide and continuous voltage setting is available using a single rod and observations sharply marked may be taken with an ordinary laboratory galvanometer or with a telephone receiver.

The usual method of setting for a definite voltage is to read the temperature inside the instrument, set the pressure at a particular value based on the value of δ, corresponding to the desired voltage setting, and which may be read from a table based on Formulas (7) and (8) and then slowly raise the voltage until corona appears, as indicated by telephone or galvanometer. While this would probably be the more common usage in connection with insulation testing and other similar service, the instrument may also be used for measuring an unknown voltage. In this case the pressure would be set for a voltage known to be higher than that to be measured and the pressure then allowed to fall slowly, its value being read at the instant corona appears. Formulas (7) and (8), or tables computed from them, would then give the value of the voltage.

The corona voltmeter would appear to have several advantages over the needle and sphere gaps; among them may be mentioned the following:

(a) Freedom from disturbance by proximity of neighboring conductors or extraneous electrostatic fields.

(b) A 2 per cent inaccuracy is the minimum claimed for the sphere gap. With careful manipulation and good circuit conditions it is certain that a corresponding figure of better than 0.5 per cent is possible with the corona voltmeter.

(c) No manipulation of high-voltage circuit. Each change of setting of the sphere gap requires altering the distance between the discharge spheres. The setting of the corona voltmeter for different voltages requires the change of air pressure only.

(d) No discharge of high-voltage circuit and no series resistance necessary. The reading of the corona voltmeter is continuous and stationary and draws no current from the high-voltage circuit.

(e) Measurement of an unknown voltage. This cannot be done with the sphere gap except through repeated opening of circuit and successive approximation.

(f) All parts of the corona voltmeter are grounded except the leading-in wire of the high-tension terminal. All dimensions remained fixed. All auxiliary circuits are at low values of continuous voltage.

(g) Permanence. The surface of a corona-forming rod remains unaffected under the continuous application of initial corona over long periods.

As regards outside dimensions, the earlier paper[1] on the corona voltmeter described a corona voltmeter for voltages under 50,000 having dimensions of 76 cm. in length and 24 cm. in diameter. The instrument shown in Fig. 9 is 9 ft. 10 in. high (of which 3 ft. is in the insulating bushing) and 1 ft. 10 in. in diameter. The inside cylinder forming the grounded terminal is 24.6 cm. in diameter and 61 cm. long. The most convenient diameters of corona rod are between 0.3 cm. and 0.9 cm. This instrument has been used for voltages up to 150,000 volts without sign of distress, this being the maximum voltage obtainable under the conditions of test. It was used for this voltage at an internal air pressure of about 135 cm. of mercury absolute, *i. e.*, not quite 15 lb. per sq. in. above atmosphere. Pressures three or four times this value could readily be used. The limiting voltage would probably be found in the flash-over voltage of the insulating terminal bushing. This bushing has a normal rating of 150,000 volts effective. It is probable therefore that the instrument shown in Fig. 9 may safely be operated without trouble to 200,000 volts maximum value.

An instrument rated normally at 300,000 volts, and which it is expected may reach 400,000 volts, is now in process of construction.

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THE DISADVANTAGES OF DURABILITY

There are certain industries which thrive on fragility; lack of durability and liability to breakage are cardinal to their prosperity; readers of Arnold Bennett will remember the play he makes in one book of the huge enjoyment of a pottery town audience, when, at a theatre, crockery smashing was in evidence; but apart from porcelain whose fragility sustains an industry by replacement. large numbers of manufactured articles are meant to enjoy only a transient and brief existence. In only one instance can engineering products be compared with those articles intended for early obsolescence, upon which, if current report be true, certain prosperous businesses are founded; this is in the case of spares whose cost is in many cases ominously high. It is not so much that the original device was ill-made, as that wear having taken place the customer is exploited because he is defenceless.

Durability is fundamental to mechanical construction, not that it is destined for eternity, but that in general it is proof against easy disaster and enjoys a reasonable span of life. Some engineering products certainly do survive a long term of service, longer in fact than their makers ever contemplated, renewals and demands for spares for very ancient plants are within the knowledge of any old established firm of reputation. While such orders are a testimonial in themselves, they invoke rather mixed feelings; had the job been less durable there would be prospect of entire replacement and more business.

Point is lent to the foregoing by the evidence before the recent Traffic Commission; it was then stated, and subsequent private inquiry confirms the statement, that no tram car belonging to the London County Council had ever been scrapped; they had been over-

hauled, repaired and periodically put into serviceable condition, but the whole number purchased were still in commission. Such a statement may invoke mingled feelings among the general public, since as ratepayers they may feel that their property is being conserved in their interests, or as passengers they may feel that their comfort is being sacrificed to parsimony; and that perhaps their journeys might be expedited if total renewal took place after a determined period. Something stronger might be said as to other means of transport, there are certain railways, for example, where archaic survivals are notorious. The term of service and survival permitted to public vehicles has few other parallels.

In machine-shop practise, although a more enlightened policy is now in evidence, antiquated survivals are pretty numerous, instances of tools approaching threescore years and ten were, not so long ago, quite ordinary, and the wisdom of such retention is questionable. The testimony to the maker is undeniable, but the profit to the user is another story altogether. Even in a time of soaring prices the retention of the obsolete has little merit, and never more so than in a time of reconstruction, when business has to be re-erected and re-won. In the matter of machine tools the need is less obvious than in power plant where running costs receive closer scrutiny, and return on capital outlay is more conspicuous. The modern analysis of power plant is very thorough and there are many rival prime movers. The business of an engineer is strictly economic, involving as it does a nicely balanced mind which senses relative proportion; on the one hand it is possible always to renew, recondition, and overhaul existing plant; on the other, every single individual will agree with the abstract proposition that there is a time in the life of every piece of mechanism when it should be discarded altogether. It is false economy to retain the obsolete, if it is not sheer parsimony, for by economic test its space otherwise filled would result in a gain on balance; the passage of time alone involves replacement if there is any virtue in evolution.

All firms who desire to be solvent have a depreciation account, of which they make the most to the representative of the Inland Revenue, and severe official attitude in restraint of exuberant writing down, adds to the contents of the national treasury. The point is, does this adjustment of income-tax in the form of abatement get duly applied to actual renewal? It is contended that at least the amount of such allowance should actually be spent in a definite policy of replacement, irrespective of whether or not the existing plant can be made to serve another term.

There is value in the policy indicated, in the place of piling up a reserve for contingency which is better employed in improving means of productive output. The assets are undeniable in either case, except that the interest earned by up-to-date gear is likely to be much the greater. Many shops are aware of the precaution of renewal and pursue a definite program but there are others less well advised. The old proverb about the shoemaker's wife contains more than a grain of truth.

In certain cases which have a bearing on the subject, machines are in existence (more particularly in agriculture) where the whole of the original has disappeared; every season portions are replaced until virtually nothing remains; the cost of such replacement is out of all proportion to initial value and illustrates one danger of easy spares facilities, the same can easily be true of motor vehicles, and a large trade in spares is valuable considering the prices charged.

Again, a parsimonious spirit defeats itself; in how many instances, when control has been vested in such an individual, has his successor to put right the lack, by royal spending. The first man took credit for economy; the second points out that to save, it is necessary to spend; both can allege reason for their views, difference of opinion would be avoided by laying down a rational program.

Actuarial assessment on the assurance principle of probable expectation of life seems feasible, the annual depreciation account indicates as much, what is wanted in many cases is execution of its provisions by term discard and renewal. To bring the old servant in the form of machine-tool or plant, to the sacrificial altar of the cupola perchance needs courage, but sentiment in such connections is out of place and iconoclasm in order; careful selection of a modern successor has advantages easily realized upon due reflection.—*Engineering*, London.

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*Inactive at present. **Total 62**

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Characteristics and Performance of Arc Welding Machinery

BY A. M. CANDY

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THIS paper deals rather briefly at first with the earlier history of arc welding apparatus discussing the increased efficiency of the constant-potential welding circuit and decreased size and cost of the apparatus by changing the generated circuit potential from 75 to 60 volts. Curves are given showing the efficiency increase and also the disadvantages attending any material decrease of the circuit potential below 60 volts.

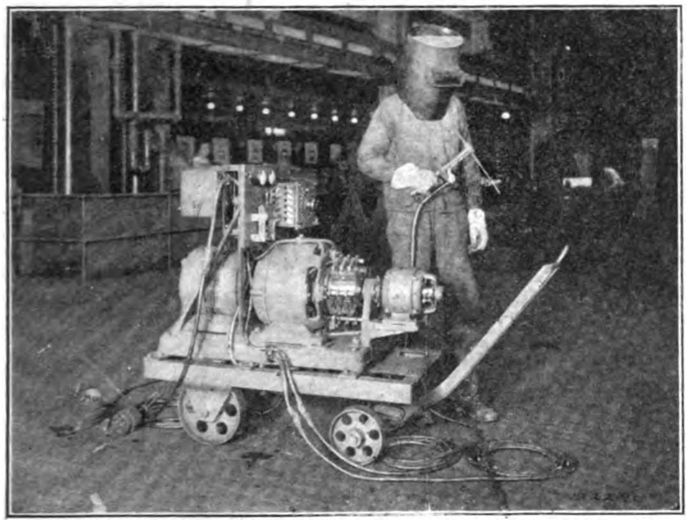

FIG. 7

The discussion then turns to the more recent developments of variable-voltage or constant-current equipment of both the alternating and direct current types. Although the a-c. arc welding transformer is about one-half as heavy and expensive as the d-c. equipment its use at present and in the immediate future at least will be relatively limited for several reasons.

1. To make the equipment commercially successful in the hands of the average welder it is necessary to use an especially prepared electrode.

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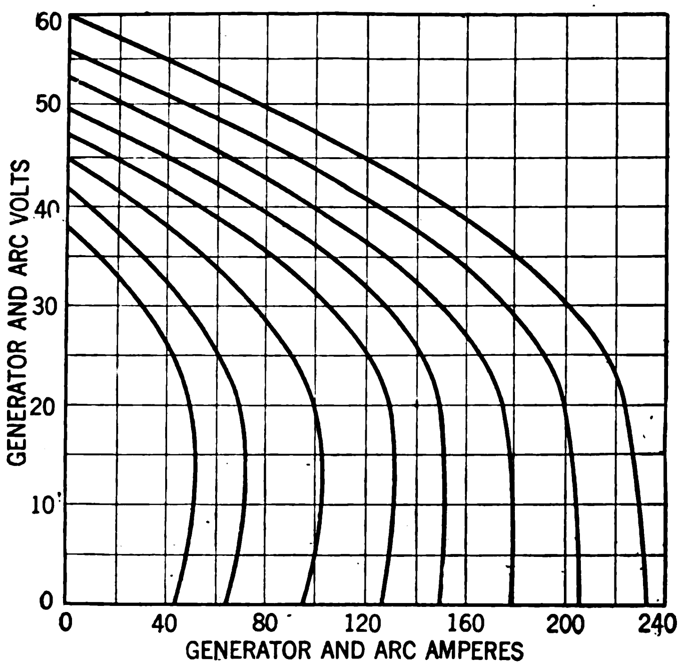

FIG. 5—SINGLE-OPERATOR ARC WELDER—VOLT-AMPERE CHARACTERISTIC

2. The alternating current arc is not so effective in fusing metal as the direct current arc assuming the same current in amperes in each case. In other words, to obtain the same rate of fusion the ratio of alterna-

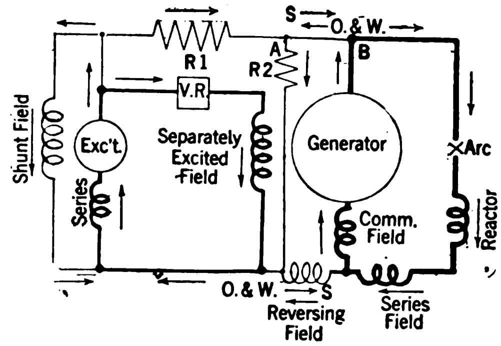

FIG. 8

ting current to direct current required is in the order of 170 amperes a-c. to 140 amperes d-c.

3. The transformer is inherently a single-phase low power factor load (20 per cent to 30 per cent maximum). This characteristic is necessary so that the arc will be reasonably stable.

The first two features make the operating cost so much higher than for the interconnected constant-current d-c. machine that the saving in operating cost per annum will be about 50 per cent interest on the difference of the first costs of the two types.

4. No thoroughly satisfactory means of limiting the open-circuit voltage to reasonably safe values (60 volts or less) has as yet been developed. To be commercially satisfactory the transformer must either actually develop or have the characteristics of an open-circuit potential of 135 volts minimum to 175 volts maximum.

This potential is higher than the operator should be subjected to as it is a real life hazard.

The main portion of the paper discusses an interconnected constant-current variable-voltage d-c. generator and exciter (see Fig. 7.) which has been developed and placed on the market quite recently. The generator is a commutating-pole machine provided with a series of field winding, a shunt field winding separately excited continually by means of a small exciter coupled to the generator shaft, and a second hunt field winding connected to both the generator terminals, and the exciter terminals so that under open-circuit and normal welding conditions it is self-excited by the generator voltage, whereas under short-circuited arc condition it is excited in the opposite direction by current from the exciter terminals. This field winding is therefore logically called a reversing field. The series field is connected so that it always opposes the separately excited field. Under open circuit and normal welding conditions the reversing field (self excited by generator) assists the separate field in maintaining the generator voltage. Under short circuited arc conditions the reversing field is excited by current from the exciter so that it functions as a separately excited field and assists the series in opposing the separate field thereby limiting the generator voltage to a value such that the short-circuit current is substantially the same as the normal welding current. This characteristic is illustrated by Fig. 5. The scheme of connections producing these characteristics is illustrated by Fig. 8. A very decided advantage of this interconnected scheme is the fact that the arc is given the advantage of the constant potential continually developed by the exciter although the generator terminal voltage is never above 60 and varies from that value down to practically zero when short circuited.

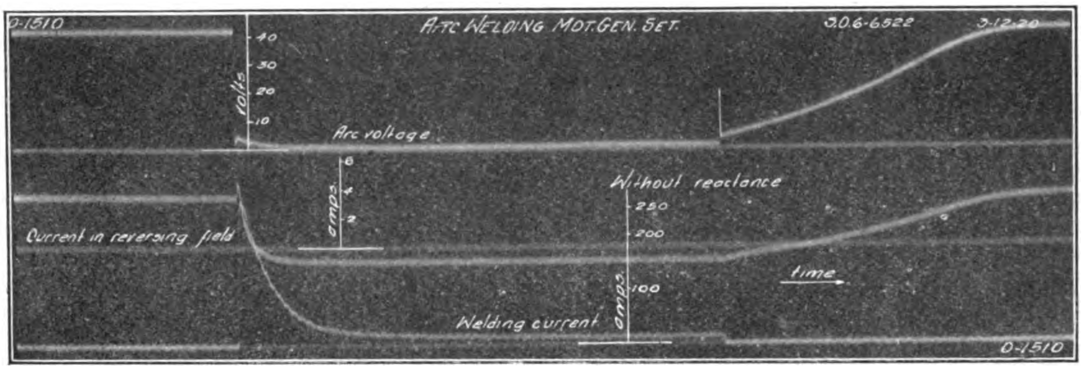

FIG. 10

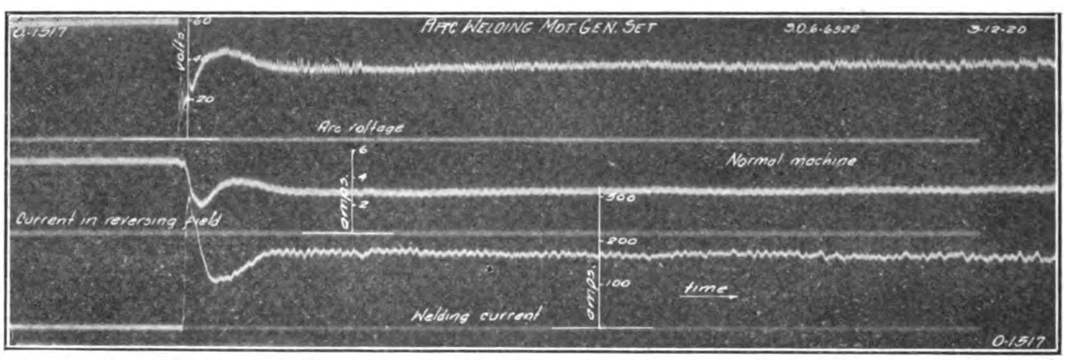

FIG. 18

A portion of the exciter voltage exists across the electrode terminals instantly when they are separated by the operator incident to striking the arc, thereby materially assisting him in starting the arc regardless of any lag in the generator building up its voltage. Furthermore, this impressed constant potential from the exciter circuit helps to stabilize the arc making it

exceptionally tenacious. Both of these features are of very material assistance to the welding operator. The latter characteristic is illustrated by Fig. 10 where the kick in the generator terminal voltage is indicated when the arc current was broken suddenly by deliberately separating the electrodes quickly.

Another feature of this machine is that it can be successfully used for graphite electrode welding, delivering 150 amperes at 40 volts, as illustrated by Fig. 18. Where more than 150 amperes is required two or more equipments can be operated in parallel by simply connecting together the external leads of like polarity of the generators. Due to the characteristics of the generator no equalizing connections are necessary.

Due to the elimination of losses in resistances in series with the arc the operating cost for the interconnected constant-current machine is considerably less than for the 60 volt constant-potential equipments and of course proportionally smaller than for 75-volt constant potentia lequipments. A curve and typical example comparing the operating cost of six interconnected machines with that of a 1000-ampere, 60-volt machine feeding six welding circuits are given. The figures show that although there is a difference in first cost of approximately $2050 in favor of the 1000 ampere equipment, under normal average operating conditions where central station a-c. service is 3 cents a kw-hr. the annual saving resulting from the use of the interconnected equipments is equivalent to practically 60 per cent interest on the additional investment of $2050.

Summary of the advantages of the interconnected constant-current scheme,

1. Ease of striking arc.
2. Ease of holding arc due to increased stability.
3. Operating expense less than for other types of equipment.
4. Simplicity of obtaining current adjustment.
5. Generator polarity cannot be reversed even though exciter circuit should be accidentally opened.
6. Two or more generators may be operated in parallel for graphite welding without requiring equalizer connections.
7. A maximum of 225 amperes for metal electrode and 150 amperes for graphite can be obtained from one generator.

Recent Developments in Electro-Percussive Welding

BY DOUGLAS F. MINER

Westinghouse Electric & Mfg. Co.

Condenser Type of Welder

FOLLOWING the original experiments of Mr. L. W. Chubb in 1905, machines were built for welding wires by the electro-percussive process and these have been used in a limited way for lamp leads, copper terminals on aluminum coils and similar applications.

These machines utilize the discharge of an electrolytic condenser to fuse the wires substantially simultaneous with a percussive engagement. With this equipment, perfect welds are made between like and unlike metals, even those of widely different physical characteristics, but the field of application has been narrow because of the state of development of condensers. A condenser of sufficient capacity to provide energy for welding large sections would be prohibitive in size.

Electromagnetic Type of Welder

Within the last year, equipment has been developed which successfully welds stock up to ½ in. (1.27 cm.) diameter, and large sizes will apparently offer no difficulty. The same principles are used in this device, but stored electromagnetic energy replaces electrostatic energy. Establishment of a strong direct-current field in a reactance coil with a primary and secondary winding is followed by rupture of the primary current with the secondary circuit closed. Transfer of energy of the collapsing field to the secondary results and a subsequent separation of electrodes in this circuit establishes

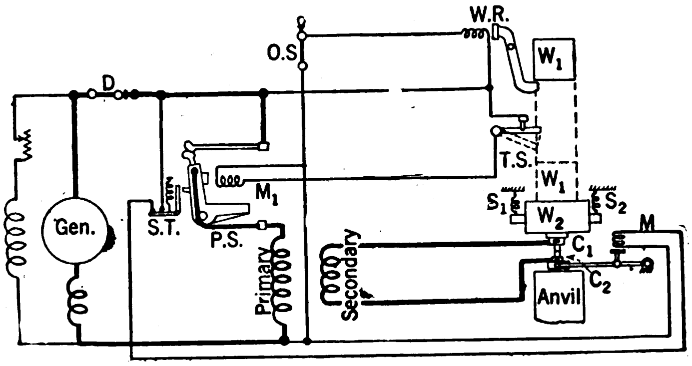

Fig. 2

an intense arc. When the surfaces of the electrodes (pieces to be welded) are sufficiently melted, a hammer forges the parts together.

The total time of the above operations is of the order of 1/10 second. Thus the weld can be said to be practically instantaneous. In an experimental welder, these events were secured in proper sequence by apparatus represented diagrammatically in Fig. 2. A cycle

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of operations is somewhat as follows: The primary is energized by closing switch D which also raises the lower electrode C_2 into contact with C, by means of magnet M. Then operating switch $O\,S$ is opened and magnet $W\,R$ de-energized. The hammer falls and in its travel knocks out switch $T\,S$. This allows primary switch $P\,S$ to open, kicking out trip $S\,T$, which then opens the secondary circuit by allowing the lower electrode to drop to the anvil. An arc is thereby established until the hammer strikes W_2, forging the parts together.

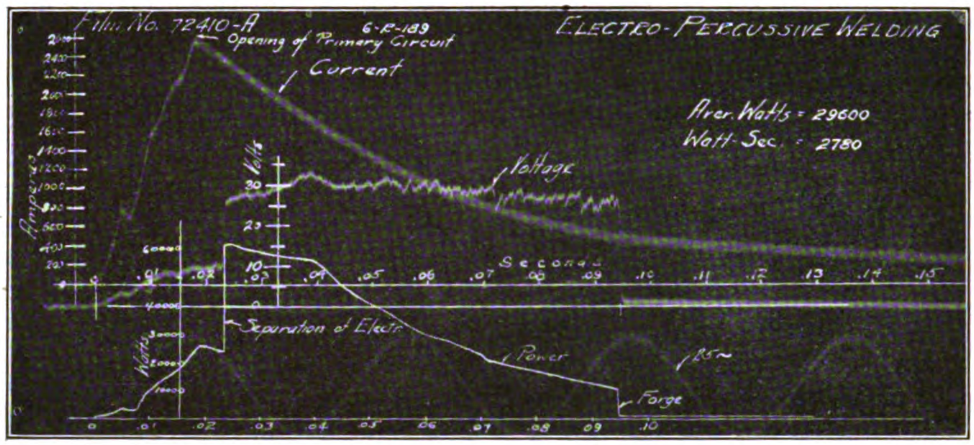

Fig. 5—Oscillogram of Electro-percussive Weld Between ⅜-in. Cold Rolled Steel and ⅜-in. Copper

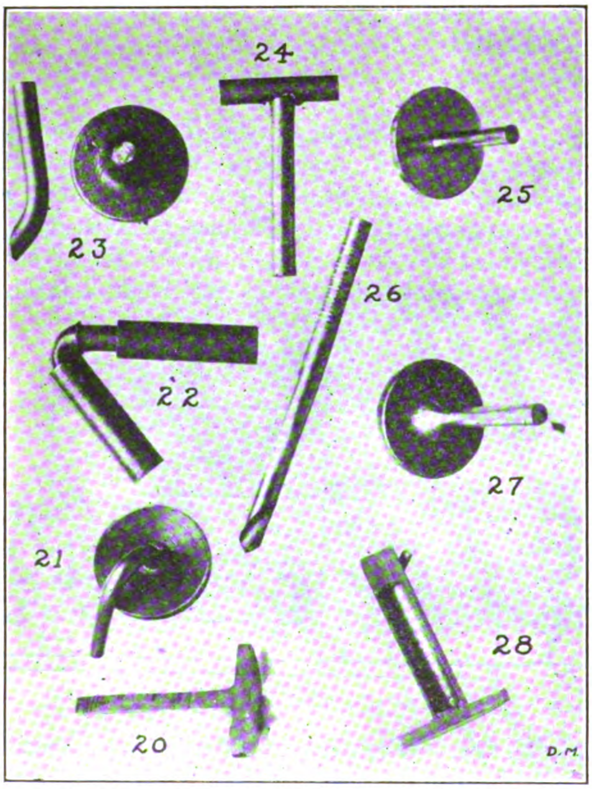

Fig. 9—Examples of Electro-percussive Welding

A record of events is given by the oscillogram Fig. 5. This indicates secondary quantities for a weld of 3/8 in, diameter stock and shows the following: Maximum secondary current 2600 amperes, arc voltage 30 volts, maximum watts 60,000, average watts 29,600, total time 0.094 seconds, energy 2780 watt-seconds or .00077 kw-hr.

A few sample welds are shown in Fig. 9, illustrating a variety of work.

20. ¼ in. copper rod welded to steel disk.
21. ¼ in. steel rod welded to steel disk and tested in bending without failure.
22. $\frac{5}{16}$ in. copper-copper weld bent sharply without failure.
23. Nickel-steel valve head welded to cold rolled steel stem. Failed in bending outside weld.
24. T-weld of cold rolled steel.
25. Cold rolled steel rod and disk polished.
26. $\frac{5}{16}$ in. drill lengthened with low carbon stock.
27. Nickel steel head to C. R. S. valve stem.
28. ½ in. hollow steel rod welded to steel plate.

Tests have shown a high strength of weld—96,000 lb. per sq. in. for steel-steel and 40,000 lb. per sq. in. for copper steel. Microphotographs confirm the quality of the weld and indicate an inter-penetration of metals, without visible alloying, and a thorough fusion without oxidation.

Advantages of Process

Some of the points of superiority of electro-percussive welding are:

(a) *Power Saved.* Power used in the weld is about $\frac{1}{16}$ that required in butt-welding*.

(b) *Time Saved.* The operation is so rapid that the time of weld is practically negligible. Speed of production will, therefore, depend chiefly on time of handling peices, and large output can be obtained by design of semi-automatic apparatus.

(c) *Welds of Unequal Sections.* Necessary energy is concentrated in a very small amount of material and not dissipated in heating the whole stock. Consequently welds of unequal section are possible

Electric Welding, D. Hamilton and E. Oberg P. 49.

without preparation of surfaces or preheating of large piece.

(d) *Welds of Unlike Metals.* with widely different physical characteristics are made possible.

(e) *Welds without Change of Condition.* Tempering or other treatments are not destroyed because heat is localized and rapid.

(f) *Welds Uniform.* After proper settings, unskilled labor can produce uniformly perfect welds.

(g) *Finishing* is unnecessary in some products and inexpensive in all because of small fin or flash.

Extension of the original process has met with gratifying success and when details of design are perfected, a wide field of application for electro-percussive welding is expected.

Credit is due C. F. Wagner and E. L. Hillstrom for aid in development.

Arc Welding Machinery of the U. S. Light & Heat Corporation

BY W. A. TURBAYNE

Electrical Engineer, U. S. Light & Heat Corporation

THE U. S. Light & Heat Corporation produces only the single-circuit or single-operator type of arc welding machine, wherein control of the current accompanying inverse changes in arc voltage and length is accomplished by inherent action of the machine windings, unaided by interposed circuit resistors.

In developing this equipment it was sought to reduce the machine and circuit losses to the lowest possible value compatible with practical operation, to obtain the quickest possible voltage response by the generator, or current converter, at the time of striking and manipulating the arc, and to insure the maintenance of a steady and stable arc, with a minimum amount of circuit reactance. It was also considered desirable to produce such a machine characteristic that the product of voltage and current would remain reasonably constant at the value best suited to the operation, despite the unavoidable variations in arc length incident to manipulation of the electrode in the hands of the operator. Provisions were incorporated, however, whereby by a simple adjustment, the slope of the volt-ampere characteristic could be altered in such a manner that practically a constant current would be maintained in the welding circuit, regardless of appreciable variations in arc length and voltage, this characteristic being favored by many operators.

Two distinct classes of arc welding machine were developed—one a *direct current generator* adapted to be separately driven by any form of motor, determined by the available source of power supply, and the other a *direct current converter* which is self driving when supplied from a direct current source having from 100 to 125 volts pressure.

The *generator* is a self-exciting, cumulative compound-wound machine, and current regulation is effected solely by the reaction of the armature current upon the field flux.

The relations between pole span and pole pitch and between the shunt and series field ampere turns are so chosen, with respect to the armature structure that, while a pronounced drooping voltage characteristic results, perfect circuit stability obtains at any value of current within the working range of the machine. A definite open-circuit voltage setting is inconsequential as the machine has a pronounced series characteristic, and a moderate variation in the shunt field current does not materially affect the current setting although such adjustment of the shunt field current affords a ready means of modifying the current values determined more or less broadly by means of a current-adjusting switch provided for the purpose.

To insure quick response to circuit conditions, the magnetic structure throughout is laminated, and the sensibility of the machine is decidedly enhanced by the inductive or transformer action resulting from the close association of the shunt and series field windings.

For operation on electric supply circuits, a compact motor-generator is furnished, induction motors of suitable voltage, phase and frequency being provided for use on a-c. circuits, and direct-current motors of appropriate voltage for d-c. supply.

The motors are direct connected to the generator, the rotor being pressed on the elongated armature shaft thereby eliminating the necessity for bolted couplings.

The complete running gear is supported on annular ball bearings and before assembly is thoroughly checked as to static and running balance.

Generators are also provided, direct connected to gasoline engines, or supplied merely with pulleys, enabling them to be driven from any available or suitable source of power.

For locations where 100 to 125-volt d-c. supply is available the *direct current converter* is recommended.

This machine has but a single magnet frame, arm-

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ature winding and commutator, and combines within itself the functions of a shunt-wound motor and a variable-voltage generator. In size, weight and appearance it corresponds closely to the generator previously described. The complete field structure also is laminated.

The field system comprises two main poles supporting the shunt field winding and two smaller auxiliary poles, spaced at right angles thereto, which carry the regulating windings. These latter comprise a shunt winding connected across the supply circuit and an opposing series winding included in the welding circuit. A field rheostat is provided in the shunt circuit for purposes of adjustment.

The armature conductors are placed in slots located substantially 120 degrees apart around the periphery and are connected to the commutator to form an ordinary two-path winding with symmetrical end connections.

Four sets of brushes engage the commutator. Two sets, in line with the main poles and diametrically, opposed, admit current from the source to drive the machine. Two other sets, one each displaced 60 degrees from a main brush, together constitute one terminal of the welding circuit, the other terminal being the main brush midway between them.

Current regulation is effected by varying the flux distribution under the poles and, therefore, the voltage around the commutator by inherent action of the windings on the auxiliary poles. These auxiliary poles are of like polarity at any instant and, depending on the degree of their excitation, act to increase the flux density in one of the main poles while decreasing it in the other.

With the converter running idly as a motor, the open-circuit voltage effective on the secondary or working brushes is brought to the desired value by means of a field rheostat, provided for controlling the auxiliary shunt field current. Upon closing the welding circuit, however, current traverses the auxiliary series opposing winding, resulting in a decrease or even reversal of the flux in the auxiliary poles, a simultaneous lowering of the flux in one of the main poles and a corresponding increase in the other. This transfer of flux causes an immediate drop in voltage on the working brushes and corresponding increase across the remainder.

Two-thirds of the armature conductors at any instant carry only the input current, the other third carrying the difference between the output, or working current, and the input current. The resultant distribution of current, therefore, is such that conductors of comparatively small section may be employed as compared with those necessary in a generator of equivalent capacity.

During operation the current in the welding circuit comes, partly from the supply mains, this being the input current which drives the machine, the balance being contributed by the machine through generator action.

As a welder the direct-current converter shows an efficiency of 65 to 70 per cent. With 200 amperes and 20 volts at the welding arc the current demand from a 120-volt source is substantially 25 per cent of the value of the welding current or 50 amperes.

Differing from a generator, in which the flux in the complete structure is varied to produce regulation, the converter flux is simply transferred from one portion to another. Consequently, a notable freedom from lag exists.

Automatic Arc Welding Apparatus

BY S. R. BERGMAN and R. L. UNLAND

Both of General Electric Co.

AMONG the requirements which must be met by arc welding equipments are simplicity and reliability. Their importance is increased by the fact that in a great many cases these equipments are installed and operated in locations where no trained electrical help is available. A new type of arc welding generator is described which inherently possesses the electrical characteristics desirable for single operator arc welding generators. This results in the elimination of external resistors or other regulating devices since the generator delivers at its terminals the voltage required by the arc and the current for which the equipment is adjusted.

It has been found that a drooping volt ampere characteristic or a circuit in which the current decreases as the voltage increases, or vice versa, is advantageous for successful electric arc welding. This has been obtained in the past by the use of constant potential generators with a resistance in series with the arc to provide the drooping characteristic in the arc circuit. It has also been accomplished by using differentially wound generators with a separate excitation source to provide a stable magnetic circuit to act as a base for the regulation of the generator. In the generator described this result is accomplished by what may be called a dual magnetic circuit.

In the generator described the design consists of a four-pole field structure and an armature wound for two poles. The field poles are paired to give two adjacent poles of each polarity. The opposite field poles have the same character and are similarly connected in the electrical circuit so that variations in the

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excitation occur simultaneously in the opposite poles and consequently the flux may be considered as two individual circuits, each of which passes through a pair of opposite poles, the armature and the field ring. These two fluxes are independent of each other as long as the magnetic structure common to both is not saturated. One of the magnetic circuits, referred to as the main field, is designed to provide constant flux and thereby maintain constant voltage in that portion of the armature under the influence of this field. The field poles in this circuit are designed to be saturated under normal conditions and therefore the flux will be very slightly affected by considerable variations in the electrical circuit. The other component of the field is at right angles to the first and is referred to as the cross field, and in this circuit the magnetic structure is not saturated. These two individual fields generate electromotive forces in the armature which under no-load conditions add arithmetically to provide the no-load voltage of the generator. As current is taken from the load brushes of the generator, however, an armature reaction is built up which may be resolved into two components at right angles, in line with the field fluxes described above. One component tends to increase the main field flux, the other component opposes the cross field flux. On account of saturation in the main field magnetic circuit further increase of flux is impossible, but in the cross field circuit the initial flux is reduced as the current and armature reaction increase and when the generator is finally short-circuited this flux is reversed to a value equal to the initial value. As the cross field is reduced and finally reversed it is obvious that the electromotive force generated in the armature by this flux also decreases and is finally reversed. The line voltage of the generator consists of the sum of these two voltage components. Under the no-load conditions they are equal and on short-circuit the component due to the cross field has the same value as at no-load but is reversed so that the terminal voltage of the generator is zero.

A differentially connected series winding is placed on the cross field poles to assist the armature reaction when it is desired to reduce the current output of this generator.

It is a simple matter to produce a generator which under steady load conditions has the drooping characteristic considered desirable for arc welding but when used for arc welding such machines fail due to slow regulation and the lag between the sudden variation in the arc and the corrective electrical or magnetic adjustment in the machine. It should be borne in mind that the regulation of this generator is mainly produced by the armature itself. Since the armature is the seat of the induced voltage it is obvious that if the armature itself is the seat of the regulating power this action is as intimate as can be obtained.

A new development is also described which takes the form of a device for automatically feeding a bare wire electrode into the welding arc at the exact rate required to maintain constant electrical conditions in the arc. This device consists of a small direct-current motor geared to feed rolls and electrically connected across the welding arc through control with the result that the speed of the motor and consequently the rate at which the wire is fed into the arc varies with the voltage across the arc. The result is that practically constant voltage is maintained across the arc and therefore the current will be constant. The arc voltage may be maintained below any value which is possible with hand manipulation of the electrode, and due to the steadiness of operation the speed of welding may be greatly increased over that obtained by hand. The length of the arc can be maintained at a minimum with the result that the metal has little opportunity of being oxidized in passing through the arc and the metal deposited is therefore of a higher and more uniform quality than that found where hand operation is used. The field for this device is limited to manufacturing production where the number of duplicate welds is sufficient to warrant the making of special fixtures for holding the work and for facilitating handling. Illustrations of work performed and operating data are given.

STATUS OF THE WATER POWER BILL

The Water Power Bill was reported back to the Senate and House after agreement by the conferees. The House promptly accepted the conference report after a short debate by a decisive vote of 259 to 30. In the natural course of events this practically assured the early passage of the bill into law but quite a formidable filibuster has developed in the Senate. When this issue goes to press, it appears that the bill is in serious danger unless the conferees make further changes in it.

It will be recalled that the bill has had a treacherous path through many sessions of Congress and that it was lost by a narrow margin in the filibuster and legislative jam that came at the end of the last session of Congress. Those in favor of the measure, however, are in hopes of forcing a vote.

It will also be recalled that after passage of this bill by both Houses considerable delay resulted in conference, due to the inability of the conferees to agree on points of difference concerning principally the appointment of executive secretary, definition of navigable waters and limitations for awards on severance damages incurred on recapture of property at the end of the fifty-year license period. The original provision for severance damages as provided in the first House bill was restored by the conferees. Some are of the opinion that the definition of "navigable waters" as given in the conference report will make it impossible for anyone to build a dam for any purpose in any creek or small stream which empties into a navigable river without first obtaining a license from the Federal Power Commission.

Power Factor in Polyphase Circuits

Preliminary Report of Special Joint Committee

THE subject of power factor in polyphase circuits has been the center of increasing discussion in recent years. No agreement has yet been reached upon a definition of the term as applied to polyphase circuits, nor even upon the underlying purpose which a definition should serve to express. In the absence of a practical commercial incentive to a universally accepted understanding as to the purpose and use of the term, little progress has been made toward such an understanding.

There has been no practical incentive for the reason that, until recent years, most polyphase loads were approximately balanced, while the differences between various possible definitions of power factor become of importance only in unbalanced loads, so that no refinement of definition has been needed. At present, however, there are increasingly important developments in types of industrial power loads which are attended by unbalanced conditions between the phases, unbalanced as to amount of loads and as to phase relations between current and voltage. In such cases the numerical value of power factor may vary widely with different definitions.

The increasing commercial importance of this character of load and the growing tendency toward such refinements in power contracts and rates as will reflect accurately the various elements entering into cost of service, have combined to render this power factor problem a matter of immediate and urgent practical importance.

In recognition of the importance of this need, the American Institute of Electrical Engineers, acting through its Standards Committee, and the National Electric Light Association, acting through its Technical Section, have united in the formation of a Committee to be known as the Special Joint Committee on Determination of Power Factor in Polyphase Circuits.

It was decided that this joint Committee should place the results of its labor before the parent organizations by which it had been appointed, namely, the Standards Committee of the A. I. E. E. and the Technical Section of the N. E. L. A. in a form which should indicate the conclusion already reached by the Committee but which would permit of further consideration and discussion by the two parent bodies before a definite solution is reached.

Two definitions covering two different forms of power factor in polyphase circuits were arrived at, together with some suggestions as to proper qualifying terms to apply to each definition. These definitions are as follows:

Definition 1. Power factor in a polyphase circuit is the ratio of the total watts to the (arithmetical) sum of the volt-amperes in the several phases, each measured to a non-inductive neutral point. This definition may be otherwise expressed as the weighted mean of the individual power factor in the phases (weighted according to the volt-amperes in each phase.)

Definition 2. Power factor in a polyphase circuit is the ratio of the total watts to the vector sum of the volt-amperes in the several phases.

A bibliography prepared by Dr. P. G. Agnew and Professor A. E. Kennelly is given as Appendix II to the report. Abstracts and translations of the work of the Italian, Gino Campos and of the German, Dr. F. Niethammer, have been prepared by Mr. W. H. Pratt and are attached to the report as Appendix III. These papers are of basic importance in considering the subject of polyphase power factor.

Polyphase Power Factor

BY F. C. HOLTZ

Chief Engineer, Sangamo Electric Co.

IN a single-phase circuit the various factors relating to power and energy are very clearly defined. For example, power is defined as the rate of energy transfer; apparent power is defined as the product of the r. m. s. value of voltage across the circuit by the value of the current in the circuit.

An interesting development is to take the mathematical expressions which give proper interpretation to the single-phase problem and extend the investigation to include the three-phase problem.

In the single-phase problem we arrive at an expression for power in the form $P o = A + j B$ in which A is the true power and B is the reactive power or volt amperes. The apparent power is given by $\sqrt{A^2 + B^2}$ while the power factor is $\frac{A}{\sqrt{A^2 + B^2}}$ and the reactive factor is $\frac{B}{\sqrt{A^2 + B^2}}$.

Upon applying the same ideas to the investigation of the three-phase problem it develops that there is a one to one correspondence between the two. Power being expressed in the form $P \phi = A \phi j + B \phi$ where $A \phi$ is again the true power as measured by any of the well known methods and $B \phi$ is the reactive power or

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volt amperes in the three phase circuit. We also have that the apparent power is $\sqrt{A^2\phi + B^2\phi}$ while $\frac{A\phi}{\sqrt{A^2\phi + B^2\phi}}$ and $\frac{B\phi}{\sqrt{A^2\phi + B^2\phi}}$ are the three phase power factors and reactive factors respectively.

It is shown that the power factor as defined by the above is in accord with the vector definition for power factor as outlined by the committee. The absurdities which result from using the arithmetic definition of power factor are shown.

The problem of measuring the apparent energy in the three-phase circuit under the vector definition involves the necessity of integrating a quantity of the form $\sqrt{A^2\phi + B^2\phi}\,dt$. An instrument to do this must therefore integrate the square root of the sum of two squares. Such an instrument may be quite easily constructed.

For example referring to Fig. 7, we may assume two vector quantities in the same plane starting at a given instant $t\,o$ from some point O, one moving in the direction of $O\,Q$ and with a velocity which is a function of the time T, the other moving at an angle from $O\,Q$ and in the direction $O\,P$ with a velocity which is also a function of the time. At a time $\delta\,t$ after starting we have the two values $O\,P$ and $O\,Q$ and the difference $Q\,P$ which represents the approximate integral of the two vectors over the time $\delta\,t$. Suppose further that we construct two mechanically moving rods arranged at the proper angle to each other. To the point P is attached a flexible cord which passes over the point Q to a small drum located somewhere on the rod $O\,Q$ or its equivalent. Attached to the small drum is counter or other device which records accurately the length of $Q\,P$ removed from the drum and through auxiliary devices the points P and Q are returned to zero at definite intervals. It is so arranged that the mechanism of the drum shall record the sum of the lengths $Q\,P$.

$$\sum_{1}^{m} P\,Q = P_1\,Q_1 + P_2\,Q_2 + \ldots\ldots + P_n\,Q_n$$

where $P_1\,Q_1$ represents the value of $P\,Q$ during the first interval, $P_2\,Q_2$ represents that during the second interval of time etc. From this it is quite apparent that $\sum_{1}^{m} P\,Q$ will represent as close an approximation as is desired to the true integral of the two vector quantities. This can be regulated by regulating the time interval of reset $d\,t$.

The integration of the volt-ampere-hours in an alternating-current circuit is a specific case requiring the application of the above. In this case the vectors are located at right angles to each other and the mechanical device is operated directly from the contacts of two watthour meters.

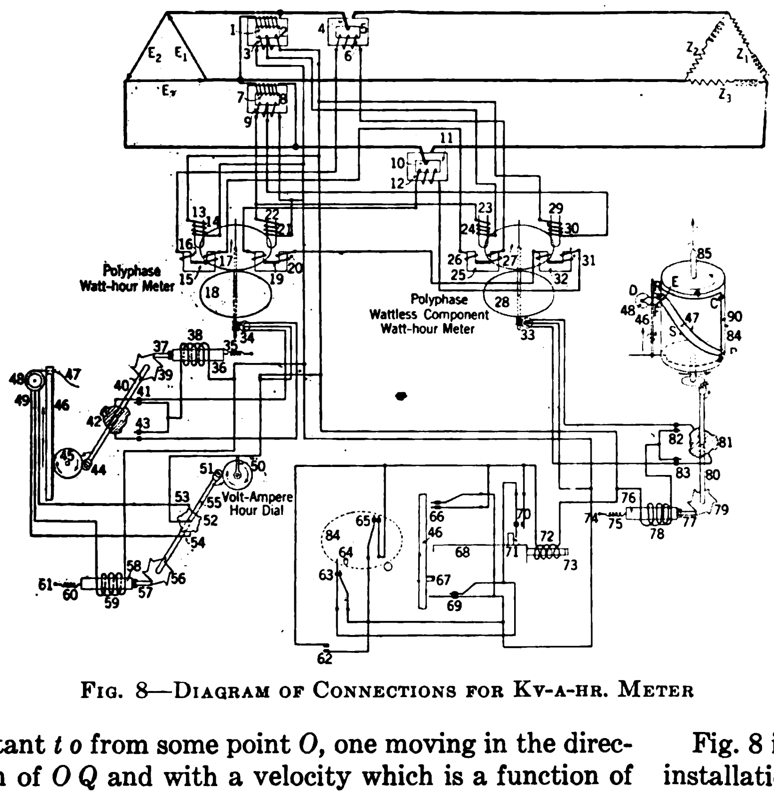

Fig. 8—Diagram of Connections for Kv-a-hr. Meter

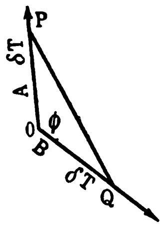

Fig. 7

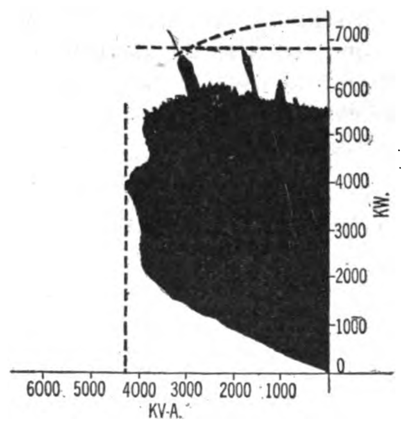

Fig. 9

Fig. 8 illustrates the case of a three-phase three wire installation.

Here the two meters are shown connected to the instrument transformers. One is so connected as to register the watthours while the other integrates the reactive component. The contact devices are represented by 34 and 35. To the right of the figure is shown the assembled mechanism, the other part of the drawing is used to represent the electrical circuits involved. Instead of using two rods operating at right angles to each other one is replaced by a rotatable cylinder in order to economize on space and increase the accuracy of the instrument. One of the moving elements consists of a drum 48 attached to a vertical

rack 46 and so arranged that with each contact of the wattless component meter the drum is rotated through a definite angle. The small drum 48 carries a silk cord 47 which passes through an eye F and is attached to the drum 84 at P. It is so arranged that with the drum 48 attached to rack 46 and drum 84 in their zero position the points P and F coincide.

Let us assume now that both meters are under rotation. With each contact at 34 the vertical rack 46 is stepped up a definite amount and with each contact at 35 the drum 84 is rotated through a definite angle. After a given time interval, say 10 minutes the positions of rack 46 and drum 84 are as shown. The cord removed from the drum 48 will be the length between P and F. Under conditions of design the rotation of 84 is proportional to $\int_{T_1}^{T_2} W\,dt$ and the height of F above its zero position is $\int_{T_1}^{T_2} R\,dt$ so that $\overline{PF} = \sqrt{W^2 + R^2}\,dt$ which is the apparent energy during the time interval. At definite time intervals contact 62 is closed and through operation of solenoid 72 both rack 46 and drum 84 are returned to their zero position. This operation is continued so long as the system is in operation.

Drum 48 carries a three-lead contact 49 which is used to operate a distant dial mechanism so calibrated as to read directly in kv-a-hr.

In addition to the cord 47 a card 90 is mounted on the drum 84 and to the rack 46 is attached a stylus R'. With each interval of operation a new line is marked on the card 90 and length of which will determine the maximum demand in kv-a.

Fig. 9 is representative of about how one of these cords would appear after a month's operation. The date taken from this chart is as follows:

1. Maximum demand in kw. 6800.
2. Maximum demand in reactive component 4300 kv-a.
3. Maximum demand in kv-a. 7400.
4. P. F. at maximum demand $\frac{6700}{7400}$ = 90.6 per cent

Measurement of Power Factor on Unbalanced Polyphase Circuits

BY R. D. EVANS

General Engineer, Westinghouse Electric & Mfg. Co.

THE object of this paper is two-fold, first, to give a scientific definition of power factor, and, second, to describe devices for measuring power factor and devices for measuring unbalance of a polyphase system.

On the Definition of Power Factor

Power factor is a term which describes the flow of energy in an alternating current circuit and which expresses a relation between the amount of energy converted into heat or mechanical work, and the amount of energy periodically absorbed and discharged in the circuit. Power factor is not the simplest factor related to true power and reactive power, but it is a convenient factor, as it expresses a ratio between the amount of power actually delivered in a circuit, to the amount of power which might be delivered without exceeding the same heating.

Power factor may be defined as the ratio of true power to the square root of the sum of the squares of the true power and the reactive power.

$$\text{P. F.} = \frac{P}{\sqrt{P^2 + Q^2}}$$

In the above expression, P is the algebraic sum of the watts, and Q is the algebraic sum of the reactive watts in all of the component parts of the circuit.

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It is to be noted that the definition of power factor, from the standpoint of the flow of energy, is complete, and is independent of the presence of harmonics, plurality of phases, or unbalance, that is, the definition requires no extension to take care of these cases. On the other hand, the definition of power factor, from the standpoint of phase difference, or the ratio of watts to volt amperes, requires modification to take care of the complication resulting from the presence of harmonics, plurality of phases, or unbalance.

Devices for Measuring Unbalance of a Polyphase System

Any system of unbalanced voltages may be resolved into two or more balanced systems of voltages of different phase sequences, each of which may be measured by stationary instruments. The meter for measuring positive or negative sequence voltage, on a three phase, three-wire system, consists of a voltmeter with two windings and two external series impedances of different power factors. Another form of this instrument is described, and this consists of a standard voltmeter, two external impedances, and two standard potential transformers.

In a similar manner, the positive and negative sequence currents may be measured. Such an instrument is described and consists of a standard ammeter, two external impedances, and two standard current transformers.

The theory of these meters is explained from differ-

ent viewpoints. One explanation is based on a physical interpretation of the mathematical solution. Another explanation is based on showing that the voltages of one sequence causes the meter to read and the voltages of the other sequence do not, and, therefore, in the presence of two sequences, the meter measures a quantity proportional to one of them. A third explanation is based on the idea of a network in connection with a meter element. From this point of view, it is only necessary to provide a network that permits only current of the desired sequence to flow in the branch in which the meter is connected.

Power Factor Meters for Unbalanced Circuits

Having separated out the positive and negative sequence voltages and currents, the next step is to combine them for measuring power, reactive power or reactive volt-amperes and power factor. Standard instruments supplied with positive sequence voltage and current, measure positive sequence watts, positive sequence reactive watts or reactive volt-amperes, or positive sequence power factor. A meter is described which measures positive sequence power factor.

In an unbalanced system, as many separate meter elements are required to measure the total power, total reactive power, or the total power factor, as there are sequences of power present. A meter is described which measures total power factor on a three-phase, three-wire system. This meter consists of two single-phase power factor meter elements, mounted on a common shaft, and one element supplied with positive sequence voltage and current, and the other element with negative sequence voltage and current.

Conclusion

Power factor, reactive factor, power and reactive power, must be defined so that their mutual relations are shown, and so that they correspond to the physical facts. A scientific or exact definition of power factor must first be formulated, and then on this foundation, a practical definition for use in rate making may be built.

The exact definition of power factor should be based on the flow of energy. Power factor is the ratio of true power to the square root of the sum of the squares of true power and reactive power.

It must be recognized that power and power factor do not completely describe the flow of energy, and that the use of some unbalance factor is necessary. Standard instruments may be employed to measure the unbalance of a system.

Power factor and unbalance are independent quantities and should be charged for separately.

Polyphase Power Factor

BY H. L. WALLAU

Electrical Engineer, Cleveland Elec. Ill. Co.

THE Special Joint Committee on Determination of Power Factor in Polyphase Circuits has formulated two definitions for this factor.

As technicians will doubtless all agree that Definition 2 which is mathematically accurate must be adopted to represent that quantity which today is referred to as power factor when applied to single-phase or to *balanced* polyphase circuits.

As commercial engineers we must recognize that Definition 1 has a broad field of usefulness, when applied to unbalanced circuits.

The central station industry today is compelled to take on single-phase loads of considerable magnitude.

These loads consist of welders of very poor power factor, (20 to 40 per cent) single-phase arc furnaces of relatively better (35 to 70 per cent) but nevertheless poor power factor, and in some cases single-phase railway loads also of poor characteristics, together with both inductive and non-inductive loads of other kinds.

If it were commercially practicable to compel the consumer to install phase-balancers or motor generator sets in connection with such loads, the inherent difficulties due to out-of-balance loads would be done away with. Obviously, this is impossible. As a result the companies must operate under certain disadvantages, with these loads connected to their systems, such as reduced effective capacity of three-phase circuits, increased heating in cables, etc. In addition, if the out-of-balance becomes of sufficient magnitude at the power plant, generator troubles will result.

Increased costs of supply result therefrom. Either the rates in our industrial schedules must reflect these added costs and proportion them over all consumers alike, or some means of penalizing the consumers causing the added burden must be incorporated therein.

This means is conveniently provided by a power factor clause. If, however, a strictly technical definition is adopted for incorporation into rate schedule, it takes no account of the effect of unbalanced currents yielding as it does a higher power factor than that obtained by the proposed commercial Definition 1.

To care for this condition a new factor, termed balance factor, has been suggested. After we have defined this factor in a manner satisfactory to all, what practical means will we have of obtaining it, and if obtained

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how shall we apply it? Its commercial use in rate schedules in addition to a power factor clause introduces a new stumbling block over which the prospective customer must be safely lifted. For that reason for commercial work Definition 1 is preferable.

This view is that of an engineer of a supply company interested in obtaining a definition that can be used in contracts for the sale of power, and is relatively simple and easily understood.

Definition 1 takes into account the maximum wattage obtainable based on the currents and voltages existing, and the ratio of this quantity to the actual watts measured is the power factor which, the author believes, should preferably be standardized for commercial work.

The name of the Committee suggests the next essential step. Not only must we define polyphase power factor, but we must determine a suitable, reliable, inexpensive and uniform method of measuring the quantity defined.

To date neither definitions nor methods are standard with us. There is a real need for both.

Power Factor in Polyphase Systems

BY FRANCIS B. SILSBEE

Associate Physicist, U. S. Bureau of Standards

THE use of a number of different definitions of "power factor" as applied to unbalance polyphase system has led to much confusion. The present paper points out the mutual relations of a number of possible definitions and their relative merits for specific types of circuits.

Power factor has two distinct applications for economic and technical purposes respectively, and the selection of the single property which any one definition of power factor can determine must be considered from two distinct points of view. The economic importance arises from the fact that it is more expensive to supply a given power to an actual load in which the currents are not in phase with the voltages or in which the currents in the several phases are not equal in magnitude than it is to supply a standard load in which some or all of these adverse conditions are absent. Three distinct types of standard load have been tacitly assumed in the development of the several definitions now in use: (A) a balanced load in which both the currents and the voltages are symmetrical and in phase; (B) a load in which the currents have the same magnitudes as in the actual load but in which the current system as a whole has been shifted in phase with respect to the voltage system, so as to make the total power a maximum (i. e., such a shift as would be produced by a symmetrical polyphase synchronous condenser); and (C) a load in which each current has the same magnitude as in the actual load that has been individually shifted into phase with its corresponding voltage.

There are also two distinct items of cost which must be considered (1) the fixed charges on the additional generator and line capacity required to supply the actual low power factor load and (2) the cost of the additional power lost in the generating circuits. The ratio of the actual power to the power which might be supplied to a standard load either (1) by the same generator capacity or (2) with the same power loss, may be taken as the logical economic definition of power factor.

For a standard load of type A and a symmetrical polyphase generator the most logical power factor is the ratio of the watts to the "effective volt-amperes", this latter quantity being defined as the product of the square root of the sum of the squares of the live currents multiplied by the square root of the sum of the squares of the voltages to neutral. For a standard load of type (B) the "vector power factor" (Def. 2 of the special joint committee) and for a standard load of type C the "arithmetical power factor" (Def. 1) are most logical.

For technical purposes it is highly desirable to separate the effects of phase displacement, unbalance and wave form since the causes and remedies for each are quite distinct. This can readily be accomplished by defining one or more additional quantities so that one quantity (such for example as "vector power factor") indicates the phase displacement as distinct from unbalance; and a second quantity (such as balance factor) shows the symmetry of the loading as distinct from any general phase shift. The first quantity thus shows the extent to which conditions might be improved by the installation of synchronous condensers, while the second indicates the possible gain from phase converters or by rearrangement of the load.

For the first quantity the vector power factor is undoubtedly most useful. It is independent of the potential of the neutal point to which the voltages are measured, and also it may be obtained by adding the real and reactive components of the individual branches of any network. It is directly related to the mean magneto and electrostatic energies of the system and to the amount of excitation required.

"Balance factor" is useful principally to indicate (1) the pulsations in instantaneous power and (2) the increase in heating of the generators which results

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from any unbalance. If the voltages are symmetrical these two properties depend upon the same combination of variables and may both be covered by a single definition. If, however, the voltages are not symmetrical this relation no longer holds and a uniform flow of power may result from a very unsymmetrical system of currents and voltages which would produce considerably increased heating. A convenient definition for the heating aspect is "effective balance factor" equals $\frac{\text{vector volt-amperes}}{\text{effective volt-amperes}}$, since this leads to the relation: Effective balance factor $\times$ vector power factor = effective power factor; and serves to reconcile the economic requirement for a single factor based on heating effects with the technical requirements for a separation of phase shift and unbalance.

In the complete paper the various possible "volt-amperes", pulsation in power and related quantities are expressed mathematically so that their interrelations may be noted, and a number of numerical examples are worked out. The generalization of the definitions to include cases where the wave forms are not sinusoidal, and the instrumental methods for measuring the various quantities involved, are also discussed.

Polyphase Power Representation by Means of Symmetrical Coordinates

BY C. L. FORTESCUE

Engineering Dept. Westinghouse Electric & Mfg. Co.

THIS paper is a more complete presentation of the subject of power representation by means of symmetrical coordinates, which was briefly outlined in the author's paper on Symmetrical Co-ordinates presented at the 30th Annual Convention, 1918.

A short treatment of the subject of single-phase power is given, and it is shown that the product $\check{E}\,\check{I} = P + j\,Q$, where P is the true power and Q the reactive power, completely specifies all characteristics of the power when the phase of the e. m. f., $\check{E}$ is given. The phase of the double-frequency component $P_H + j\,Q_H$ is as much in advance of $\check{E}$ as $\check{E}$ is in advance of $P + j\,Q$.

The question of single-phase power measurements is touched on. It is shown that the wattmeter is normally a reactive power meter. It is only a true power meter when the current in the voltage coil is constrained to be proportional to, and in phase with, the impressed e. m. f. The watthour meter measures energy by reason of the fact that the current in the voltage coil is constrained to be in quadrature to the impressed e. m. f. If it were constrained to be in phase with the impressed e. m. f., which could be just as easily accomplished, this instrument would integrate the mean reactive power.

It is shown that four measurements are required to completely determine a single-phase load mathematically; the two complex variables $\check{E}$ and $\check{I}$, furnish all the necessary data.

In practical measurements, it is usual to specify the impressed e. m. f., the kilovolt-amperes, and the power factor; the true phase of the impressed e. m. f. being arbitrary.

A symmetrical polyphase system requires for its complete determination four quantities which are usually

1. The e. m. f. of one phase.
2. Its phase angle.
3. The current in one phase.
4. Its phase angle.

The particular phase under consideration may be termed the "principal phase."

Since an unbalanced n-phase system of currents and e. m. fs. may be resolved at most into n symmetrical systems of currents and e. m. fs., the maximum number of measurements required to completely define such a system is $4\,n$ and the minimum number may be from 4 up to $4\,n$ depending upon the nature of the dissymmetry.

The quantities expressed in symmetrical co-ordinates required to completely define a three-phase, four tone system are:

$S^\circ\,\check{E}_{A0}$, $S^1 E_{A1}$, $S^2\,\check{E}_{A2}$ the symmetrical components of e. m. f. and $S^\circ\,\check{I}_{A0}$, $S^1\,\check{I}_{A1}$ and $S^2\,\check{I}_{A2}$ the symmetrical components of current. The sequence symbols have the following significance. The S° system consists of three equal vectors of the same phase. The S^1 or positive phase sequence system consists of three equal vectors each of which lags $\frac{2\,\pi}{3}$ behind the preceding vector when taken in their alphabetic order. The S^2 or negative phase sequence system consists of three equal vectors each of which leads the preceding vector by $\frac{2\,\pi}{3}$ when taken in alphabetic order. These sequence symbols have the property of combining by the law of indices when products of two sequences are formed.

Instantaneous symmetrical systems are formed from the symbolic systems in exactly the same manner as for single-phase, and by following the same procedure

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for obtaining the power products as in the treatment of single-phase system, we obtain similar expressions as in single-phase, and the zero frequency system of power vectors obtained completely specify the whole system of power vectors.

In an unbalanced three-phase, three-wire system there are three systems of zero frequency power vectors. The S^0 system consists of the true and reactive power due to the positive and negative sequence currents and e. m. f., and S^1 and S^2 systems whose instantaneous value is zero; they represent interchange of power among the phases, and therefore, are a measure of the degree of unbalance. It is shown that if the true and reactive power of each phase of a system are given and true power is taken as datum and the vectors so formed are resolved by the method of symmetrical co-ordinates, the systems of power vectors deduced above are obtained.

Three-phase power measurements are discussed: It is shown that in all the usual power measurements, the true and reactive power due to positive phase sequence and negative phase sequence appear as entities and may be separated. They are therefore not mathematical fictions but actual concrete quantities.

All true and reactive power measurements by symmetrical co-ordinates methods may be accomplished by a single movement. A comparison is made between the present method of measurements and those following the principle of symmetrical co-ordinates. The same number of instruments are required in each case but the symmetrical co-ordinate method completely determines all necessary factors without computation.

A method of graphically obtaining the complete solution of a system when measurements are given is shown.

The author holds that it is of the highest importance that definitions of the fundamental quantities and factors concerned with the measurements of e. m. f. current, power and energy be scientifically correct. It is not vitally important in practical work that all definitions shall be adhered to, but it is vitally important that our standard definitions be based on sound scientific principles.

Definition of Power Factor. Power factor shall be determined from measurements of three-phase power by means of two or more wattmeters connected in the usual manner and from reactive power measured by a reactive power meter with the same connections as those used in measuring the true power. If P be the true power and Q the reactive power

$$\text{Power factor} = \frac{P}{\sqrt{P^2 + Q^2}}$$

The positive phase sequence power factor and negative phase sequence power factor are obtained in a similar manner.

Definition of Unbalance Factor. The ratio of one unit of the negative phase sequence component of a quantity to the corresponding unit of its positive phase sequence component is defined as the *unbalance factor* of the quantity under consideration. Usually the ratio of the magnitudes only need be considered.

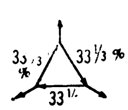
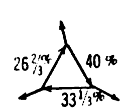
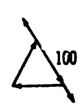
Conclusion. The definitions proposed are easily measured and completely and uniquely determine all the quantities it is necessary to know in order to make proper charges for energy.

Polyphase Power Factors and Unbalanced Loads

BY PHILIP TORCHIO

Chief Electrical Engineer, N. Y. Edison Co.

DEFINITION No. 1 in the Committee's report gives a numerical relation applicable to any polyphase circuit, which is also intended to give a measure, as a general average, of the greater outlay of apparatus and plant that the supply of unbalanced loads entails. Without attempting to state whether such numerical averaging gives a fair compromise measure of the added economical burden of carrying unbalanced loads, it is important that we definitely and clearly describe the results of the applications of this definition No. 1. For this purpose I submit in the table herewith comparative results of the amount of capacity of electrical equipment required for generating and transmitting a unit amount of power under different conditions of unbalancing, all giving the same average value of power factor definition No. 1:

	Capacity of electrical equipment required for generating and transmitting 1000 kw. of		
	Balanced load	Unbalanced load	Unbalanced load (Single phase)
Power factor by definition No. 1 per cent			
100–99.5	1000 kv-a.	1100 kv-a.	Not possible
86.6	1150 "	1250 "	1740 kv-a.
75.0	1330 "	1425 "	2000 "
50.0	2000 "	2175 "	3000 "

The above comparison shows that, with apparently the same value of polyphase power factor, the capacity of electrical equipment required for generating and transmitting the same amount of power may vary as much as from 1 to 1½. It is obvious that under such

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extreme conditions the cost of service would be quite different in the several cases.

On the other hand, the unbalanced load of one customer may be compensated by the contemporaneous unbalanced loads on other phases of other customers, so that, as a net result, on the supply company's equipment only a fraction of its equipment may be affected by the "apparent" low power factor due to unbalanced loads, this effect being perhaps limited only to the district where the power is distributed, but being balanced and equalized on the transmission line and the generators.

The power rate engineer may, therefore, have greater need of the *"comtemporaneous unbalanced loads and power factors of definition No. 2"* for the individual customer and for the district, than the average power factors of definition No. 1.

In this connection it would seem wise to make reference to the importance of defining the time intervals during which the power factors are to be taken. It will be of particular value to the power rate engineer to have *power factor diagrams* for the twenty-four hours for the customer and district under consideration, rather than the power factor for one minute or fifteen minute period of maximum demand or the average power factor for the twenty-four hours, which will be of small value to him in analyzing the cost of such service. The same comment may be made as to the recording of unbalanced loads.

Power Factor and Unbalance on a Polyphase System

BY CARL J. FECHHEIMER

Designing Engineer, Westinghouse Electric & Mfg. Co.

In a single-phase or balanced polyphase circuit, the two factors which are contributory to power factors less than unity are wave distortion and phase displacement between current and voltage. In the paper the influence of wave shape is not considered, since in most large modern systems the wave form is nearly sinusoidal. The paper covers balanced and unbalanced polyphase systems without neutral current.

Power factor and unbalance are two distinct phenomena; therefore any attempt to formulate a definition which combines them is certain to be meaningless and of very questionable value.

The general case of a polyphase system is treated from the standpoint of two polyphase systems of opposite phase sequence. A proof is given that the usual unbalanced system of currents in machines is physically made up of two balanced systems of opposite phase sequence, thereby showing that the method is more than a mathematical convenience. In Appendix A, a physical proof is given for the fact that in the rotor of a synchronously driven single-phase induction motor or synchronous machine, double frequency polyphase currents are induced which are productive of m. m. f. which is constant in magnitude and rotates at synchronous speed in the opposite directions to the rotor, and this m. m. f., when combined with the alternating m. m. f. due to the stator currents, gives a resultant m. m. f. which is constant in magnitude and revolves at synchronous speed in the same direction as the rotor. In the induction motor the flux is proportional to this latter m. m. f.; in the alternator it is the "armature reaction." Thus, the alternating m. m. f., due to the single-phase stator currents gives rise to two equal and opposite m. m. f., both traveling at synchronous speed but in opposite directions.

In Fig. 2, OA is the m. m. f. of the polyphase double frequency rotor currents, which rotates negatively at synchronous speed. OD is the alternating stator m. m. f. which is fixed in position; and OC is the resultant of the two, which rotates in a positive direction at synchronous speed. The same final results would have been obtained had OD been taken as the resultant of OC, of positive rotation, and OB, equal and opposite

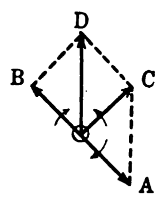

FIG. 2

Time angle = 30 deg.
Stator m. m. f. = 0.853 × 2 = 1.732
Rotor m. m. f. = 1, shifted clockwise 30 deg.
Resultant = 1, shifted counter-clockwise 30 deg.

to OA, and of negative rotation. Then the alternating m. m. f., OD, is the resultant of two equal m. m. fs, constant in magnitude, both rotating synchronously in opposite directions. One m. m. f. is productive of flux (or armature reaction); the other is that which is needed to neutralize the rotor magnetizing or damper currents.

In a polyphase machine, a rotating m. m. f. is produced by a polyphase system of currents, and therefore the two oppositely rotating m. m. f. systems in Fig. 2, may each be so represented, as in Figs. 3 and 4 where four-phase systems are shown. These combined give the single-phase system of Fig. 5.

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Two equal three-phase systems of opposite phase sequence may be similarly combined to give a single-phase system. If the balanced negative sequence system is decreased in magnitude, or changed in phase relation to the positive sequence system the resultant is an unbalanced polyphase system. Conversely, the unbalance polyphase system may be broken into two

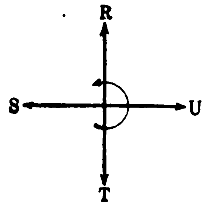

FIG. 3

Time angle = 45 deg.
Stator m. m. f. = 0.707 × 2 = 1.414
Rotor m. m. f. = 1, shifted clockwise 45 deg.
Resultant m. m. f. = 1, shifted counter-clockwise 45 deg.

balanced polyphase systems of opposite phase sequence; in appendices B and C are given illustrative methods, graphical and analytical, for doing this. This method of solving the unbalanced system is unique in that there *is but one solution* for any given system; on the other hand, the method of breaking into a balanced polyphase and superimposed single-phase systems permits of an infinite number of solutions.

The same general law for losses that applies to the

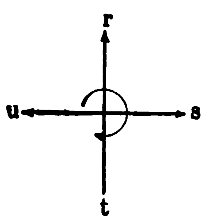

FIG. 4

Time angle = 60 deg.
Stator m. m. f. = 0.5 × 2 = 1
Rotor m. m. f. = 1, shifted clockwise 60 deg.
Resultant = 1, shifted counter-clockwise 60 deg.

in-phase and quadrature components of current, and the combination of currents of different frequencies, namely, the "sum of the squares" law, applies also when the unbalanced system of currents is broken into its constituent positive and negative sequence systems; this is proved in appendix D.

The deleterious effects of a relatively small unbalance in voltage upon synchronous and induction machinery due to a not inconsiderable unbalance in currents are discussed; especially is this so with synchronous converters. The negative sequence currents in such apparatus, due to unbalance in line voltage, tend to correct the unbalance of the system, and these negative sequence currents are in consequence displaced 180 deg. from those negative sequence currents which produce the unbalance.

In any case, the true power in the polyphase system is the sum of the power in the positive and that in the negative sequence systems; similarly for reactive power the power factor is the ratio of the true power to the square root of the sum of the squares of the true and reactive powers. In general, the negative sequence voltage and power are small compared with the positive, so that the following definitions are proposed:

"The power factor is the ratio of the true watts to the volt-amperes in the balanced positive sequence systems of volts and amperes."

"The unbalance factor is the ratio of the negative sequence amperes to the positive sequence amperes."

Thus, the proposed definition for power factor fits in with the usual idea: it is the cosine of the angle between current and voltage in the positive sequence system.

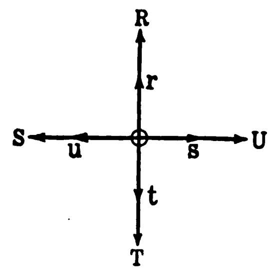

FIG. 5

Time angle = 90 deg.
Stator m. m. f. = 0
Rotor m. m. f. = 1, shifted clockwise 90 deg.
Resultant m. m. f. = 1, shifted counter-clockwise 90 deg.

The definition for unbalance disregards unbalance in voltage. Had it been expressed as "the ratio of the negative sequence volt-amperes to the positive sequence volt-amperes," it would have been undesirable because the negative sequence voltage is very largely dependent upon the synchronous and induction apparatus on the system, and consequently volt-amperes are no measure of the degree to which the system is unbalanced by a given customer.

The method of breaking the unbalanced systems into their constituent systems can be readily used in measurement, as is covered in another paper by Mr. R. D. Evans.

Parallel cases in which physical quantities are separated into their component parts are given. The most striking example is that of a distorted wave which is generated in the alternator due to the non-sinusoidal distribution of flux in the air gap. This wave is looked upon by all engineers as composed of one of fundamental frequency with superimposed waves of higher frequency. Physical evidence is also given by an oscillogram taken on the secondary of an induction motor when slightly unbalanced voltages were applied to the primary.

Eddy Current Losses in Armature Conductors

BY R. E. GILMAN

Westinghouse Electric & Mfg. Co.

THIS paper covers the development of formulas and curve data which permit of the ready calculation of the eddy current losses in armature conductors.

Previous published information on this subject has covered solid or infinitely laminated conductors and then only for the case where all the conductor currents in the same slot are in phase.

This paper first shows the development of the general formula for the loss ratio in a conductor carrying current, when located in any position in a slot with reference to other conductors, which carry currents of the same or different phase.

The loss ratio referred to is the ratio of actual alternating current loss plus the effect of eddy currents to the loss in the conductor carrying the same effective value of direct current.

The paper is then extended to cover the calculation of the loss ratio for the majority of commercial windings in common use. Present day windings consist of one or two coil sides per slot. The final formulas give the equivalent loss ratio for such a group of conductors as will be included in one coil side or as are contained in one common insulating cell from ground. These formulas cover the effect of different combinations of strand groupings as well as the effect of changing the number and dimensions of the strands. In addition, the effect of length of end windings and the use of short cord windings is given.

A series of tests results are given where various combinations of strands and groupings were used, and the loss ratio from these results is compared to the calculations from the formulas.

Temperatures in Large Alternating Current Generators

BY W. J. FOSTER

Engineering Dept. General Electric Co.

THE general public undoubtedly thinks of the size of a machine in terms of its physical dimensions or the work it can do. To the engineer, largeness involves the difficulties inherent in the design and construction. To him, a 5000 kv-a. generator at 3600 revs. per min. is large, while a 20,000 kv-a. generator at 100 revolutions is not large if considered strictly with reference to the temperature problem.

The two principal factors in the temperature problem are, first, the total losses or the amount of energy in the form of heat to be removed and, second, the means that can be provided for dissipating the heat. In a rotating electric machine three sources of heat are always involved: first, hysteretic losses in the magnetic material, second, the resistance to flow of current in the windings and, third, the frictional losses in bearings and windage.

In considering the temperature problem, the first and most fundamental consideration is the relation of the space occupied by the object to the total heat losses to be dissipated. A 20,000 kv-a., 100 rev. per min. machine compared with one of the same output at 1800 rev. per min., has its losses generated in a space eight times as great in terms of cubical space occupied, or approximately two times in the projected area occupied. We may well think of the temperature problem in terms of heat losses to space occupied. Below a certain value of this constant it is absurd to use ventilation housings, no matter how great the rating of the machine, as such housings have the effect of preventing the natural means of heat dissipation, viz., convection and radiation, and ventilation housings in such cases result in higher temperatures, unless forced draft is provided, which results in a decrease in the efficiency of the unit and can be justified only on the score of reduction of noise or some similar reason.

The author calls attention to the advantages resulting from drawing the air into the two ends of a generator directly from the dynamo room and piping it away, in connection with hydraulic units.

Water is an ideal agent for cooling purposes by reason of its high capacity for heat, but it is difficult and almost impossible to use it for removing the heat generated in the rotating element of a generator. There are objections to its use in the stationary element, such as, danger from leaks developing in the pipes and condensation on surface of pipes.

Curve sheets are given to show the importance of selecting a diameter that involves a fairly high peripheral speed. The higher the peripheral velocity the better the efficiency until the point is reached where the higher windage losses more than offset the reduced iron and copper losses.

Curves are given to show the distribution axially of

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the cooling air in stator cores as related to the sectionalizing of core and the internal temperatures of the armature coils as affected by different sectionalization.

Curves are also given to show the rate of temperature rise and the time required to reach constant temperatures in the various parts of generators of the salient pole type and also of the cylindrical rotor type.

Under the topic "High vs. Low Temperature Generators" the author advocates conservatism in temperatures for both classes of generators—the so-called low and high temperature machines for which the Institute has standardized Class A and Class B insulations. He claims longer life and better efficiencies as a rule, for generators that have low temperatures.

Classification of Large Steam Turbo Generator Failures

BY PHILIP TORCHIO

The writer classifies fifty-five generator failures of which he has a record or report. The machines are installed in different parts of this country. Their capacities range from 5000 to 30,000, the smaller size dating back from twelve to sixteen years, and the larger being of more recent manufacture.

The failures, several occurring on the same unit, are summarized as follows:

Armature failures due to:		
Mechanical damages	3	
Heating of windings	17	
Heating of iron	2	
Loose laminations	1	
Moisture in cooling air	3	
Corona shield breaking	2	
Heating at end turn clamping	1	
Causes undiscovered	2	33
Field failures due to:		
Open circuited connections	3	
Grounding	7	
Grounding caused by bus short circuit	4	
Loosening of damper windings	2	16
Armature and field failures due to:		
Moisture	1	
Undiscovered	3	4
Terminal failures due to:		
Moisture	2	2

To avoid similar troubles, designing engineers should use insulating materials of proved dependability, maintain low copper temperatures by proper subdivision of copper and transposition of strands in windings and provide liberal ventilation throughout the machine. The operating copper temperatures should be limited at or closely to 100 deg. cent. Too great range of operating temperatures is bound to cause generator failures. Mica insulation in hydroelectric generators operated at steady load will last indefinitely at high temperatures, while, under similar conditions, mica insulation in steam turbo generators operated intermittently will fail.

The test voltage for windings should be raised to three times full voltage plus 1000.

Mica and asbestos tape insulation for fields is more dependable than fibrous insulation. Solid forged fields are preferable to laminated field structures or even built-up plate structures.

Users must exercise great care in the supply of cooling air to prevent moisture or condensation depositing on the windings.

Ventilation and Temperature Problems in Turbo Generators

BY B. G. LAMME

Chief Engineer, Westinghouse Elec. & Mfg. Co.

THERE are four effective materials concerned in turbo-generator operation, namely, the iron for magnetic purposes, the copper in the windings, the insulation encasing the windings and the ventilating air. As the iron and copper have long since been carried to their practical limits, it follows that the major part of recent developments has been in the insulation and the ventilation. In fact, it may be said that the present commercial insulations for such apparatus have been utilized fairly well up to their limits for some years. Therefore, it follows that the more recent growth in large turbo-generator work has been largely along the lines of improved methods of heat dissipation, that is, of improved air circulation.

Broadly speaking, there is but one method of turbo-generator ventilation in use at the present time, namely, forcing large volumes of air through the machine at a high velocity. The systems of ventilation used may be classified as radial and axial. Both methods are used, to a certain extent, in all practical machines at the present time. These two methods of ventilation are described briefly and problems and difficulties relating to each are discussed.

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The above is followed by a discussion of the problems of heat flow in connection with the copper, iron and insulating parts, indicating, in a general way, where the principal temperature drops occur. This is followed by a general discussion of copper, iron and air friction losses and a rough indication is given as to the enormous volumes of cooling air required by such machinery.

Temperature determination is next taken up, with a short discussion of the methods approximating the highest temperature, by means of embedded detectors.

The paper is intended to be educational in the sense that it points out what the actual turbo-generator problems are, in so far as they concern turbo ventilation. It does not attempt to go into the quantitative solution of such problems.

Some Practical Experience with Embedded Temperature Detectors

BY F. D. NEWBURY and C. J. FECHHEIMER

Engineering Dept. Westinghouse Electric & Mfg. Co.

ENGINEERS are interested in the maximum armature coil temperatures and in the average temperature of the embedded portion of the coil. Only the former are discussed at length in the paper, and test data are submitted to bear out the statements; in general the test data include temperature measurements on the bare copper.

There may be very material errors due to improper installation of the detectors; and even if properly installed between coil sides, the detector does not read the maximum copper temperature. The principal reasons for the latter are that there is a flow of heat from the adjacent sides of the copper in the upper and lower coils to the slot sides, and that there is a difference in temperature between the upper and lower coils. The heat flow to the slot sides is augmented by the fact that the longitudinal thermal conductivity of built-up insulation is from three to ten times the transverse conductivity. Even with an isotropic medium the flow of heat to the slot sides lowers the detector reading. The relative side flow is increased with increase in distance between copper conductors in upper and lower coil sides.

The difference in temperature between the copper in the two coils is due principally to difference in eddy current loss, arising from the cyclic change of leakage flux. The eddy loss in the top coil is lowered if the throw of the coils in the particular slot in which the detector is placed is such as to increase the phase angle between the currents in the two coils, as is proved by test data.

The principal sources of errors pointed out in the paper, arising from improper installation of detectors between coil sides, are due to the wrapping of the upper and lower coils individually, thereby permitting cool air at the vents to lower the detector temperature, and the use of wide detectors. Test data on a 12,000-kv-a alternator and on a model of an armature with thermocouples on the bare copper, as well as between coils, with the one and two slot cell arrangements are submitted; and in addition, in the case of the model, data with wide and narrow resistance exploring coils are given. In order to show that the air currents which lower the detector readings did not lower the internal temperatures, data are also incorporated, in the case of the model, with packing between the coils. The data confirm the statements in regard to errors. It further seems from the data that there is a greater difference between the maximum and minimum readings with detectors between coils exposed to the cooling air than with detectors similarly placed but protected from the air, and the difference is smallest with detectors on the bare copper.

Detectors at the bottom of a slot in the 12,000-kv-a. alternator, and at the bottom of a slot and under wedge in a 3750-kv-a. turbo generator showed (in conjunction with readings on the bare copper) that detectors so placed cannot read the copper temperature, nor in any way give an indication of the thermal drop through the insulation. The detector reads the temperature of that part of the iron or wedge with which it is in contact.

Tests show that the copper at the top of the upper coil is not necessarily at the highest temperature, because the wedge is usually cooler than the iron. If the maximum copper temperature is sought, detectors should be placed at various depths in the upper coil.

The paper concludes with a summary, conclusions and remarks. Other points than those previously cited in this abstract are that: all heat from the copper must flow transversely through the insulation; the thermal drop through the insulation in large, long-core, high-voltage, 60-cycle machines is of the order of 50 deg. cent.; the thermal drop in the insulation, in long-core machines can not be appreciably lowered by improvement in ventilation; thermometers placed on the end

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windings, in general, give no information in regard to the highest copper temperature; resistance measurements taken after completion of the heat run, convey no information in regard to maximum temperature, and but little information in regard to the average temperature in the slots; the machine usually cools too much after shut-down and before taking readings to obtain accurate data on the average temperature of the winding.

The method of measuring temperatures by detectors in the upper coil is not usually commercial; therefore it would be best to continue with detectors between coils, protecting the detectors from external air currents. The detector reading is then a means of judging the maximum copper temperature, and as such may be used for comparison of readings between machines.

Calculation of Magnetic Force on Disconnecting Switches

BY H. B. DWIGHT

Electrical Engineer, Canadian Westinghouse Co.

THE practical problem of calculating the magnetic force tending to open a disconnecting switch is a useful one to solve. The result is expressed in concise form in formulas (**20**) and (**21**) and curves are also given in Figs. 3 and 4 from which the force may be found without using the formulas.

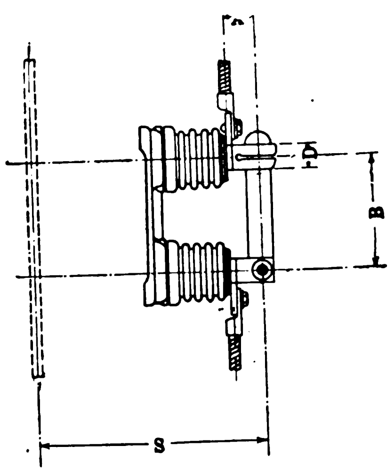

FIG. 1—FRONT-CONNECTED DISCONNECTING SWITCH

The solution of this problem is useful not only to the designers of switches who must design the parts so as to withstand the maximum force to be expected, but also to the designers of circuits containing disconnecting switches, for it is often desirable to choose a form of circuit which will produce the least possible force on the switch. The formulas and methods of calculation may also be used for calculating the forces on different parts of circuit breakers and other types of apparatus.

The mechanical force tending to move the blade of a switch which is carrying current, is proportional to the strength of the magnetic field in which the blade lies. The fundamental formula which should be used in making calculations of this kind states that the strength of the magnetic field at a point P, due to a small length of conductor $d\,x$ at a point Q is equal to

$$\frac{I\,dx\cos\theta}{P\,Q^2}$$

where I is the current in absamperes and θ is the angle between $P\,Q$ and the perpendicular from P to the line through $d\,x$. This may be found in standard text books such as J. J. Thomson's "Mathematical theory of Electricity and Magnetism," Fourth Edition page 356.

The field in which the blade lies is calculated in four parts, each depending on part of the typical circuit shown in Fig. 5.

TYPICAL CIRCUIT

This typical circuit consists of a flat blade of length B, two round arms of length A, and connections parallel to the blade. The diameter and shape of the parallel connections do not appreciably affect the result. A typical circuit of this type most nearly corresponds to disconnecting switches as used in practise, and it is believed that it gives a calculated force which is correct within a small percentage.

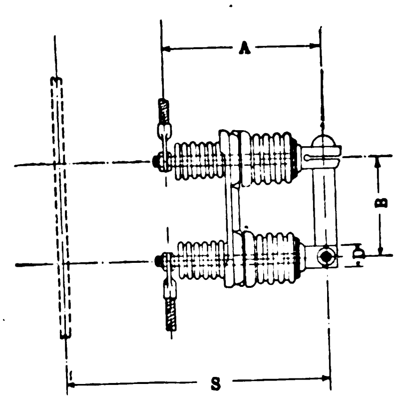

FIG. 2—REAR-CONNECTED DISCONNECTING SWITCH

The formulas are first obtained in algebraic form, but they are greatly simplified for practical use by engineers by expressing them as convergent series. Separate series must, however, be given for the two cases of A greater than B, and A less than B. For this purpose, the following series are required:

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$$\text{logh}\,(x + \sqrt{1 + x^2}) = X - \frac{1}{2.3}x^3 + \frac{1.3}{2.4.5}x^5 - \frac{1.3.5.}{2.4.6.7}X^7 + \ldots \quad (8)$$

where X^2 is less than 1, and

$$\text{logh}\,(x + \sqrt{1 + x^2}) = \text{logh}\,(2\,x) + \frac{1}{2.2}u^2 - \frac{1.3}{2.4.4}u^4 + \frac{1.3.5}{2.4.6.6}u^6 - \ldots \quad (9)$$

where x^2 is greater than 1 and where $u = 1/x$

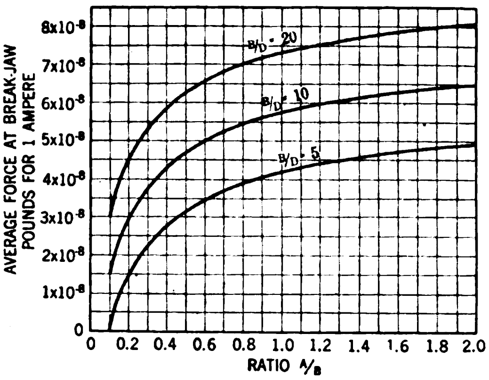

FIG. 3—REPULSION IN DISCONNECTING SWITCHES

The force varies as the square of the current.
Force due to return circuit not included.
B = Length of blade.
D = Width of break-jaw.

The force in pounds is obtained by multiplying the strength of field by the strength of the current—and by a constant depending on the units used.

The formulas for the four parts are as follows: First, the force due to flux cutting the blade, outside of the

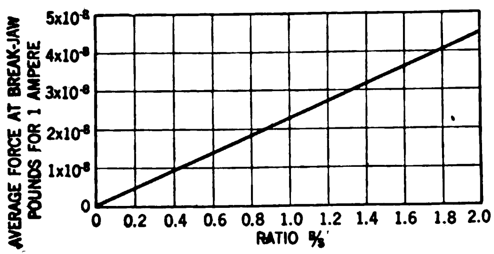

FIG. 4—REPULSION DUE TO RETURN CIRCUIT

The force varies as the square of the current.
B = Length of blade.
S = Distance from blade to return conductor.

break-jaw, caused by the conductor of length A, when A is greater than B, is

$$\frac{I^2}{4.45 \times 10^7}\left[2.30\log_{10}\left(\frac{B}{r}\right) - \frac{1}{4}\frac{B^2}{A^2} + \frac{1}{4}\frac{r^2}{A^2} + \frac{3}{32}\frac{B^4}{A^4} - \frac{1}{4}\frac{B^2C^2}{A^4} + \ldots\right]\text{pounds} \quad (10)$$

When A is less than B, the above force is

$$\frac{I^2}{4.45 \times 10^7}\left[2.30\log_{10}\left(\frac{2A}{r}\right) - \frac{A}{B} - \frac{1}{6}\frac{C^2}{A^2} + \frac{1}{4}\frac{r^2}{A^2} + \frac{1}{6}\frac{A^3}{B^3} + \frac{.1}{6}\frac{A\,C^2}{B^3} - \frac{3}{40}\frac{A^5}{B^5} - \frac{1}{4}\frac{A^3C^2}{B^5} + \ldots\right]\text{pounds} \quad (11)$$

Some of these terms are small and may be omitted.

Second, the force due to flux cutting the blade inside the break-jaw, caused by the conductor of length A, is

$$\frac{I^2}{4.45 \times 10^7}\left[\frac{1}{3} - \frac{1}{10}\frac{r^2}{A^2} + \ldots\right]\text{pounds} \quad (13)$$

This is, in an ordinary case, only about 8 per cent of the total.

Third, the force due to the connections parallel to the blade, shown by full lines in Fig. 5, when A is greater than B, is

$$\frac{I^2}{4.45 \times 10^7}\left[-\frac{B}{A} + \frac{1}{2}\frac{B^2}{A^2} - \frac{1}{8}\frac{B^4}{A^4} + \ldots\right]\text{pounds} \quad (16)$$

When A is less than B, this force is

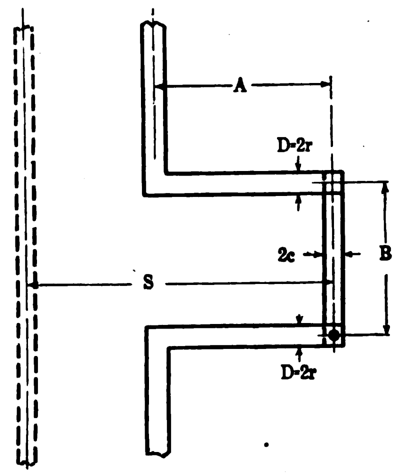

FIG. 5—TYPICAL CIRCUIT

$$\frac{I^2}{4.45 \times 10^7}\left[-1 + \frac{1}{2}\frac{A}{B} - \frac{1}{8}\frac{A^3}{B^3} - \frac{1}{8}\frac{AC^2}{B^3} + \ldots\right]\text{pounds} \quad (17)$$

Fourth, if the circuit returns directly behind the switch at a distance S, the force is

$$\frac{I^2}{4.45 \times 10^7}\left[\frac{B}{S}\right]\text{pounds} \quad (19)$$

Adding the above, the total force at the break-jaw is when A is greater than B,

$$\frac{I^2}{4.45 \times 10^7}\left[2.30\log_{10}\left(\frac{B}{r}\right) + \frac{1}{3} - \frac{B}{A} + \frac{1}{4}\frac{B^2}{A^2} + \frac{3}{20}\frac{r^2}{A^2} - \frac{1}{32}\frac{B^4}{A^4} + \frac{B}{S}\right]\text{pounds} \quad (20)$$

When A is less than B, the force is

$$\frac{I^2}{4.45 \times 10^7}\left[2.30\log_{10}\left(\frac{2A}{r}\right) - \frac{2}{3} - \frac{1}{2}\frac{A}{B} - \frac{1}{6}\frac{C^2}{A^2} + \frac{3}{20}\frac{r^2}{A^2} + \frac{1}{24}\frac{A^3}{B^3}\right.$$

$$+ \frac{1}{24} \frac{A\ C^2}{B^3} + \frac{B}{S} \Big] \text{ pounds} \qquad \textbf{(21)}$$

If I is the effective current in amperes, the force given by the formulas or curves is the average force. If I is the peak value of current as read from an oscillograph, the force is the maximum momentary force. If the circuit does not return behind the switch, the term $\frac{B}{S}$ is zero.

It would be desirable if the calculated solution of this problem were to be checked by laboratory measurements. No published measurements of the force on a disconnecting switch are known to the writer, but it should be possible to make such a measurement within an accuracy of a few per cent.

Example: $I = 30{,}000$ amperes, effective. $A = 15$ inches, $B = 20$ inches, $2\,C = 1.5$ inches, $D = 2\,r = 1$ inch. No return circuit behind the switch.

Result, the average force at the break-jaw is,

$$\frac{9 \times 10^8}{4.45 \times 10^7} [4.094 - 0.667 - 0.375 + 0.018]$$

$$= \frac{90}{4.45} \times 3.07 = 62 \text{ pounds.}$$

Using Fig. 3, $\frac{A}{B} = 0.75$ and $\frac{B}{D} = 20$

Therefore the average force is

$$9 \times 10^8 \times 6.9 \times 10^{-8} = 62 \text{ pounds.}$$

The maximum momentary force due to the above alternating current is 124 pounds.

Voltage Stresses in Reactors in Service

BY F. H. KIERSTEAD and ROYAL MEEKER

Both of General Electric Co.

THE authors have presented experimental data together with a physical explanation of the phenomena revealed. They have endeavored as far as possible to abstain from mathematics and obstruse theoretical considerations.

Comparison is made of the similarity between current limiting devices and limiting devices as regards the necessity for reliability and the authors point out the ease with which the latter may be tested and call attention to the difficulty of subjecting the former to service conditions by means of tests. The reason for the difficulty in demonstrating the ability of reactors to function properly in service is twofold. First, it is almost never possible to obtain a generator large enough to deliver the full short-circuit current through the reactor at the rated frequency and maintain across the reactor the circuit voltage for which the reactor was designed. Second, the voltage stresses that are obtained in a reactor with a generating system short-circuited through it are far more severe than would be obtained with a large generator alone discharging through the reactor. Because of this difficulty of observing the stresses in reactors while undergoing short-circuit conditions experimental data are presented indicating the magnitude of these stresses and their causes.

A large number of tests have been made with a 10,000-kilowatt generator short-circuited through reactors and it was impossible to observe the presence of high voltage stresses in the reactors.

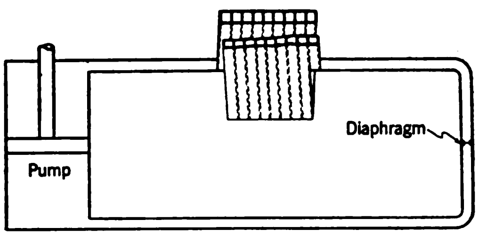

Fig. 7—No Stress on System

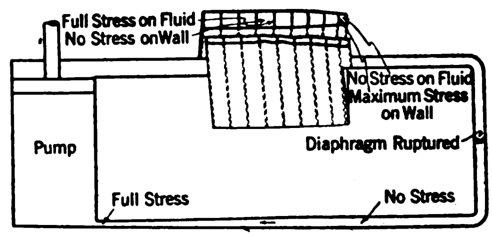

Fig. 10—System After Diaphragm Has Ruptured and Wave Has Entered Coil

If excessive voltages existed across the reactors they existed for too brief a period for the oscillogram to record them. There was no means of determining if the voltage stresses were distributed non-uniformly. The reactors showed no visible signs of distress.

In such short-circuit tests high voltage stresses may occur at the time the short circuit is made and at the time of interrupting the short-circuit current. Between these two periods there exists only the reactive voltage due to the short circuit current.

Investigation was made of the voltage stresses at the instant of making short circuits and also at the instant of the interruption of short-circuit current, and the

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results of these investigations have been included in the paper.

Attention is called to the fact that the reactors in service may have greater voltage stresses in them than could be caused by the short-circuit tests above referred to for two reasons:

1. They may be subjected to lightning impulses.
2. They may be subjected to high voltages due to resonance.

The results of both of these causes of high stresses are recorded in the paper.

A. Voltage Stresses at Instant of Short Circuit

At the instant a short circuit occurs on an electric circuit the voltage at that point drops to zero, while the voltage at all other points except those immediately adjacent to the short circuit, are still at full value, and the short circuit results in a traveling wave of steep front.

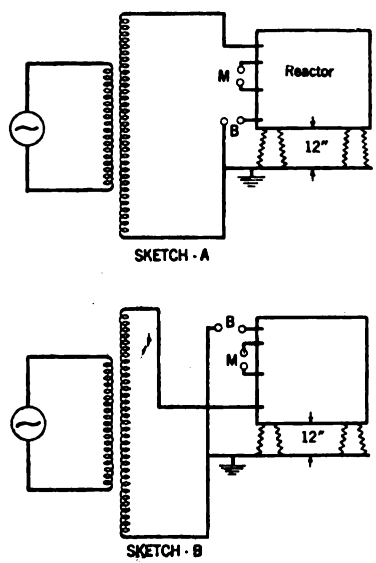

Fig. 11

In the paper it is shown how such a steep wave is caused in a hydraulic circuit and the close analogy between the hydraulic circuit and electric circuit brought out.

With experimental data it is shown that in an electric circuit a wave of not greatly over 30 ft. in length may be produced by a sudden short circuit.

A close analogy exists between the hydraulic system shown in Fig. 7 and the electric system shown in Fig. 11, and Fig. 10 shows the effect of a steep wave front on the long cylindrical ring with hollow cross sections to be similar to the effect of a steep wave front upon a reactor. The experimental data given in the paper prove that this conception is correct since the stresses which were measured between layers accords with the conception of the stresses on the diaphragm shown in Fig. 10.

Investigation has been made of the stresses between turns and layers of a reactor with and without a resistor shunting the reactor and the results show a marked reduction in stresses due to the presence of the resistor.

Summarizing, the paper shows the following:

1. That steep waves may be produced by the sudden drop in voltage caused by a short circuit.
2. That the initial distribution of a steep wave across an inductance is determined by the amount of energy stored in its capacity to ground which must be discharged in order for the waves to progress through the inductance and by the capacity between turns and layers of the inductance through which the energy must be discharged.
3. That a resistance shunting an inductance reduces the voltage stresses caused by steep waves.

B. Voltage Stresses at The Instant of The Interruption of a Short Circuit Current

The voltages that may occur across reactors at the time of interruption of a short circuit current may depend upon the switch which interrupts the current, the value of the current interrupted, the voltage of the circuit interrupted and the amount of inductance and electrostatic capacity in a circuit interrupted. In the majority of cases the switch itself acts as a safety valve limiting the voltage by drawing an arc between the blades of the switch and thereby prolonging the current until a favorable time occurs for the current to die out. To determine how the above conditions affect the voltage stresses in reactors investigations were made as follows:

1. To determine the variation in voltage rise across a reactor with the amount of current interrupted.
2. To determine the effect of different speeds of interruption of current on the voltage rise.
3. To determine the variation of the voltage rise with the point on the current wave or which the switch starts to open.

The results of these investigations are given in the paper. The conclusions, drawn from these investigations, are as follows:

1. The voltage obtained across a reactor due to the interruption of a direct current is independent of the applied voltage and depends on the current to be interrupted and the rate at which it is interrupted.
2. The voltage across a reactor due to the interruption of alternating current with commercial switches is in general independent of the current interrupted and depends on the impressed voltage, and will be approximately equal to double the impressed voltage. If, however, the circuit is opened by a switch so quick acting that the current is interrupted before it can reach its zero value in accordance with its normal curve, then the voltage will depend upon the current interrupted and the rate at which it is interrupted.

C. Voltage Stresses in Reactors Due to Impulse Waves

The paper shows the anology between the circuits which were used to produce impulses similar to lightning impulses and a hydraulic circuit. It is shown, that the effect of impulse voltages in stressing up the

reactors is similar to the case described in section A with two exceptions:

1. Both ends of the reactor feel impact of the wave.
2. The wave front is not so steep due to the longer conductors involved in this latter case.

The investigation of the effect of the impulse waves on the reactor is divided as follows:

1. The effect of shunt resistance on the voltage across a reactor.
2. The effect of shunt resistance on the distribution of the voltage stresses in reactors.
3. The effect of extra end-turn and end-layer spacing on the stresses in reactors.

The conclusions drawn from the tests of the effect of impulse voltages on reactors are as follows:

1. Impulse waves may cause non-uniform distribution of the stresses in a reactor. The distribution of these stresses between turns and layers of the reactor depends upon the distribution of the capacity between turns and layers of the reactors and upon the wave shape.
2. Resistance connected to the reactor winding effects a reduction of these voltages stresses. The amount of the reduction depending upon the magnitude of the resistance.
3. Extra spacing of the end-layers and end turns of the reactor winding causes greater concentration of voltage stresses on the extra space parts. Apparently no increased insulation strength against impulse voltages is gained by extra spacing the end turns and layers.

Attention is called to the additional advantage gained by using a resistance having the characteristics of presenting a higher resistance to low voltages than it does to high voltages.

D. Voltage Stresses in Reactors Due to Resonance

An analogy is drawn between mechanical resonance and electrical resonance. There is also shown the similarity between a generator delivering energy at the proper frequency to an inductance in series with a capacity and a large condenser delivering energy by means of oscillatory discharge at the proper frequency to an inductance in series with a small capacity. The authors measured resonant voltage across a reactor nine times as great as the applied voltage. It is explained how these resonating circuits can be obtained in ordinary generating systems. It is also shown that these voltages appear on the other apparatus and cables in the circuit.

The simplest means of preventing resonant voltages occurring is to shunt the reactors in the system with resistors. By so doing, any tendency for rise in voltage across the reactor due to resonance causes an energy loss in the resistor proportional to the square of the voltage rise and therefore the loss soon reaches a point at which it is equal to the energy delivered which fixes a maximum point to which the voltage may rise. Experimental data presented in the paper shows this to be true.

In this paper is shown a method of calculating the limits to which the resonant voltage may rise if there be no resistance in the circuit, and experimental data show the method given to be in accordance with results obtained in practise. The outstanding features of the investigation covered in this section of the paper are three-fold.

1. Resonant voltages are obtained in circuits similar to those used in electric generating and distributing systems.
2. Resonant voltages in circuits having high capacity are enormous.
3. Resonant voltages are entirely eliminated by a resistor.

The paper concludes by calling attention to a series of events that are linked together which will cause destructive voltages in reactors.

Stability of High-Power Generating Stations

BY CHARLES P. STEINMETZ

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I. Power Limitation

WITH the increasing use of electric power, the size of electric generating systems has steadily increased, from the small high-frequency stations of the early days, to the huge metropolitan systems of today. This created the problem of limiting the destructiveness of the power which can accidently be concentrated at any point of the system.

With increasing size, systems were divided into several generating stations, more economically to cover the territory, and under present conditions there appears no material gain in going much over a hundred thousand kilowatts in a single station.

Economy and reliability of operation demands paralleling of the entire system, and synchronous operation of all the generating stations thus is the universal custom.

At the high distribution voltages necessary in these systems, the impedance of lines and feeders does not materially limit the destructive power concentration possible at any point in case of a short circuit. The steam turbine type of alternator, universally used, inherently gives relatively much greater momentary short-circuit current than the low-speed machines of former times.

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Thus power-limiting devices have become necessary and are universally used in all modern high-power systems. Such consist of:

(1) *Power-Limiting Generator Reactors*, inserted between the generator and the busbars, where the internal self-inductive reactance of the generator cannot be made sufficiently high without material sacrifice of its other characteristics.

The reactance permissible in the generator leads necessarily is limited to the amount which does not materially increase the total synchronous reactance.

(2) *Power-Limiting Busbar Reactors* thus become necessary. Such busbar reactors should be as high as possible, effectively to limit the power which can flow over them into a short circuit on one busbar section, but still low enough not to interfere with such flow of current along the busbars, as required under the variations of the load.

With all the stations or station sections tied together into a ring bus by power-limiting busbar reactors, the maximum power which may have to flow over the busbar reactors theoretically is one-quarter that of the smallest generator on the busbar section. Busbar reactors thus may be of much higher reactance than generator reactors.

Interchange of power over busbar reactors occurs without voltage drop, by a phase displacement between the voltages on the two sides of the reactor, and a 25 per cent reactance, referred to the rating of one generator, is ample for the interchange of current, with negligible phase displacement.

(3) *Feeder Reactors*. Even with generator power-limiting reactors, and busbar dividing reactors, the effect of a short circuit at or near a busbar section is very severe, and probably shuts down this section. As troubles in feeder cables are very much more frequent than at the busbars, the installation of feeder reactors greatly reduces the frequency of serious troubles. While a feeder reactor may be a relatively small percentage, referred to the feeder capacity, it is large relative to the station capacity. It therefore greatly reduces the shock of a short circuit on the system, maintains some voltage on the busbars, and thus, if properly chosen, protects against the dropping out of synchronous apparatus. Also, by permitting a more rapid opening of the circuit breakers, it reduces the duration of the trouble.

The installation of power-limiting reactors made the safe operation of our huge power systems possible, and permits their increase to any size, millions of kw. generator capacity, with the same reliability and safety of operation.

The question then arises, what effect this necessary sectionalizing of the system by reactors has on the synchronizing power of the system, and thus on the stability of operation, the more so as in case of trouble a local and temporary drop of voltage may still further lower the synchronizing power.

The seriousness of this problem was again illustrated by some troubles which occurred in 1919 in the 25-cycle generating system of the Commonwealth Edison Company of Chicago: Four stations are connected together by power-limiting busbar reactors, with about a quarter million kw. of connected generator capacity, at 9000 volts. A short circuit occurring in a middle station opened and the system cleared in three to four seconds. But the voltage, which should have come back immediately after opening the short circuit, did not come back and could not be brought back, with the generators fully excited, but remained at zero in the affected station and the next adjoining one, for a quarter of an hour, while the other two stations gave low voltage. Then the voltage suddenly came back to normal. As the result of the short circuit, the two generating stations, and the individual generators in the two stations, had broken out of synchronism and were drifting past each other, unable to pull each other into step, until after a quarter of an hour.

On May 19, a short circuit occurred at the generator of one end station, immediately opened and the system cleared, but the voltage remained low and wildly fluctuating in all four stations, giving a voltage chart looking like hunting of the generating stations against each other, though it is doubtful whether it was real hunting. After a quarter of an hour, the voltage suddenly came back to normal and the stations steadied down.

The question of the synchronizing power of these big stations, as affected by the impedance between the machines, thus is of fundamental importance for their safe operation, and is further investigated in the following.

II. Parallel Operation of Synchronous Machines

A. Steady Strain. This gives the equations of the flow of power, current, phase displacement of two alternators, stations or station sections connected together through an impedance and loaded so that a steady flow of power occurs over the connecting impedance, and gives the conditions of maximum synchronizing power, etc.

B. Oscillation. This gives the equations of a system of two alternators, or group of alternators interconnected by an impedance and oscillating against each other, and discusses the synchronizing power transfer, the current flow, limits of synchronizing power, etc.

C. Slipping. This gives the equations of a system of two alternators or groups of alternators interconnected by an impedance and out of synchronism with each other, that is, slowly drifting past each other. The equations are given of the periodic power transfer, the fluctuation of current, the pulsation of speed, and the maximum frequency differences, from which the machines can pull each other into step, as related to the mechanical momentum of the machines, etc.

D. Pulling in Step. This gives the equations for the same case as *C*, when the frequency difference is too large for the machines to pull in step quickly, and derives the equations of the steady continuous power transfer, which gradually brings the machines closer together in frequency, until they are so close, that they can pull in suddenly, in a half cycle, and thereby change from slipping to synchronous oscillation which gradually steadies down to steady parallel operation.

III. Discussion

The meaning of the terms entering the preceding equations, and their numerical values, are discussed and applied, and a number of conclusions derived, such as that the synchronizing power is a maximum, when the true self-inductive reactance of the machine or group of machines is half the effective or equivalent reactance of armature reaction. The minimum voltage, at which turbo alternators still have sufficient synchronizing power to stay in step with each other when suddenly full load is thrown off, is of the magnitude of half of normal voltage.

The curves of voltage drop of turbo alternator stations as the result of a short circuit beyond a feeder reactor, and the curves of voltage recovery after the opening of the short circuit are calculated and their relation to the remaining in synchronism or dropping out of step of generators, synchronous converters, etc. is discussed.

Considerations Which Determine the Selection and General Design of an Exciter System

BY J. T. BARRON

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AND

ALEX E. BAUHAN

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It is the purpose of this paper (a) to discuss the factors which determine the selection of an exciter system for a generating station and (b) to discuss other general design features of excitation systems. No attempt is made to recommend any particular system for general application but rather to present a method analyzing the problem for a particular case.

Excitation systems may be roughly classified as:

A—Central system with separately driven exciters.

B—Central system with direct-connected exciters.

C—Individual system with direct-connected exciters.

D—Individual system with separately driven exciters.

Part I—Consideration of Factors which Determine the System to be Used

The accompanying tabulation compares in a general way the various systems from the standpoints indicated in the first column.

Part II—Consideration of Matters Related to the Layout of an Excitation System but not Mainly Concerned in the Choice of System

1. *Number and Size of Exciters.* Where system A is used for small and moderate size stations the minimum requirement is two exciters each, large enough to supply the entire excitation requirement, and the usual maximum requirement is three exciters, any two of which can carry the load. For the very large station the minimum is three exciters and the usual maximum four exciters, any two of which can carry the entire load in either case.

In systems *B* and *C* each exciter is usually made large enough to supply its own unit. Spare equipment is provided by a motor-driven set or by making direct-connected exciters oversize.

In system *D* each exciter should be large enough for its own unit with a motor-driven spare machine. Two a-c. exciters are usually provided, each of which is large enough to carry entire load. Transformer connection to main bus should also be provided.

2. *Kind of Drive.* Referring to system *A*, if two exciters are provided, both should be prime mover driven. If there are three or four exciters, at least two should be prime mover driven. Combination prime mover and motor drive may be used in hydro plants subject to ice or trash trouble and for manipulation of heat balance in steam plants. Generally speaking, induction motor drive is preferable to synchronous motor drive.

3. *Shunt vs. Compound Exciters.* The compound-wound exciter is not recommended for parallel operation especially when used with voltage regulators.

4. *Voltage.* 125 volts is satisfactory for small plants but for moderate size and large plants 250 volts is preferable from the standpoint of reduced cost and size of apparatus and cables. It is suggested that consideration may be given to the use of 500 or 550 volts in large plants.

5. *Bus Arrangements.* For system *A* and the a-c.

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COMPARISON OF SYSTEMS

	A Central Separate	B Central Direct	C Individual Direct	D Individual Separate
(1)—Power Supply to Auxiliaries	Good	Good	Not Suitable	Excellent
(2—Automatic Voltage Regulation	If used for auxiliaries or with battery requires booster system of regulation		Permits use of individual regulators	
(3)—Use of Storage Battery	Most advantageous use of battery. Requires booster system of regulation		Battery cannot be floated. Can be used only with complications	
(4)—Space Requirements	Large	Small	Small	Large
(5)—Initial Cost (A = 100%) Low head hydro	100%	70% to 90%	70% to 90%	120% to 140%
Steam or high head hydro	100%	50% to 70%	50% to 70%	120% to 140%
(6)—Efficiency (hydro, excluding rheostats)	Good	Excellent	Excellent	Poor
(7)—Effect of Power System Troubles (a) Sustained Short Circuit	Prime mover driven exciters unaffected. Speed of motor-driven exciters affected	If speed increases, higher short-circuit currents and better synchronizing power. If speed decreases, lower short-circuit currents and lower synchronizing power		Unaffected
(b) Sudden loss of load	Speed of motor driven exciters affected	Speed of exciters affected		Unaffected
(c) Generators falling out of step	Speed of motor driven exciters may be affected	Speed of some of exciters affected. Synchronizing power may be decreased		Unaffected
(d) Opening of fields to clear line trouble	Excitation unchanged	If speed is below normal generators are more likely to fall out of step due to poor reduced excitation		Excitation unchanged
(e) Splitting station with regulator potential on one section and compensating coil on other section	Voltage fluctuation equal to twice line drop compensation results		Unaffected with individual regulators. If only one regulator voltage fluctuation results	
(f) Shut-down of generator with direct-connected exciter needed for other units	Unaffected	Serious disturbance to service	Loss of excitation on a running generator which may fall out of step	Unaffected
(8)—Effect of Exciter System troubles (a) Ice and trash (hydro)	Serious reduction of service unless ample motor driven spare is available	Unaffected	Unaffected	Serious reduction of service unless ample motor driven or transformer spare is available
(b) Short-circuited exciter	Unaffected if exciter can be spared. Serious if exciter cannot be spared		If generator is large in comparison with size of system it may fall out of step	
(c) Short circuit on exciter bus	Short circuit usually clears itself. If not total interruption results		Unaffected	Short circuit usually clears itself. If not total interruption results
(d) Accidental shut-down of exciter	Serious disturbance unless exciter can be spared		Unaffected	If d-c. exciter, may cause generator to fall out of step. If a-c. exciter serious disturbance unless machine can be spared
(e) Open circuit in exciter field	Serious disturbance unless exciter can be spared		Generator may fall out of step	
(f) High voltage from opening last exciter breaker	Affects entire excitation system. May cause breakdown of insulation. Will blow fuses and breakers on auxiliary circuits		Ordinarily not possible. In any event affects only one unit	
(g) Regulator troubles	Affects entire system		Affects entire system if only one regulator is used and only one unit if individual regulators are used	
(9)—Simplicity physical	Simple for small or moderate size station. Complicated if many exciters and battery are used		Very simple for small number of generators. Complicated for large number of generators	Complicated
Normal Operation	Simplest	Simple	Simple	Complicated
During Trouble	Simple	Complicated	Complicated	Simplest
(10)—Reliability	Depends on number of pieces of equipment, amount of remote control, automatic and regulating devices.			

side of system *D*, a single bus is sufficient in most cases. A double bus gives all the flexibility that might be desired.

In systems *B* and *C* and the d-c. side of system *D*, a single bus for the use of the spare capacity and facilities for throwing any exciter either on this bus or on the field of its own generator is sufficient.

6. *Protection.* The minimum amount of automatic protective equipment consistent with safety to service and apparatus should be installed. Exciter battery and generator field breakers should have no overload protection. Exciter breakers should have reverse current trip if operated in parallel or with battery. Rotating equipment which is likely to run away should have overspeed trip. Use of electrolytic arresters to prevent high voltages is advisable. Ground detectors in the form of lamps should be used. Any overload relays used on motors should function only in case of short circuit and not when motor is pulling back after a voltage disturbance.

Factors in Excitation Systems of Large Central Station Steam Plants

BY J. W. PARKER and A. A. MEYER

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REALIZING that the excitation system is an important factor in successful operation of a large turbo-generator plant, careful attention should be given to the design of a most practical scheme. Underlying principles like simplicity, measured reliability, limited flexibility should not be lost sight of. Probabilities, rather than all possibilities should be carefully weighed and provisions made to meet only the former, rather than introduce a complication of safeguards just as apt to cause trouble.

There are two commonly found methods of providing excitation; one from a common bus, the other by means of individual exciters. A variety of schemes can be devised which are based on one or the other. The common bus method is perhaps the older of the two, but seems to be giving way to the individual exciter schemes employed in more recent practise. The important consideration is that the employment of a common exciter bus entails the maintenance of an additional energy system, secondary to the main energy system, but equally important, and requiring safeguards and careful attention to insure continuity and good regulation.

The individual exciter scheme is growing in popularity because simplification is easily attained. Disturbances in the excitation system are limited to a single generator, instead of endangering the entire plant. The scheme also lends itself well to expansion with increase in station capacity. Additional excitation equipment can be installed in like ratio with the main generator units, and without disturbing or even affecting existing equipment.

The best means of driving exciters depends upon the general method of excitation. With the common bus scheme it becomes more difficult. Prime movers are sometimes employed for driving exciters, but have not been altogether satisfactory in such small sizes as are usually required.

Motor drive has been more successful. Reliability in the latter case has been secured to a high degree by throwover to two sources of energy, one the auxiliary power bus, the other the main station bus. With the individual exciter scheme, a simple solution has been obtained by direct connection of the exciter to the main generator shaft. The exciter benefits by the good speed regulation of the most accurately governed prime mover in the plant, the main unit. The question of reliability of the prime mover driving the exciter as well as the attention of the turbine room operator to an additional machine is automatically eliminated. There is one objection raised to the direct-connected exciter, because the possible loss of the exciter entails losing from commission the corresponding main unit. This chance, however, may be so minimized as to leave very little hazard.

Standby excitation to the main generator seems more necessary with the common bus method than with the individual exciter scheme. This is evident from the fact that the exposure of the common bus is greater and trouble at any one point affects the whole plant. Standby in most cases consists of a battery floating on a common bus, usually the normal excitation bus. A battery so connected also acts very efficaciously as a stabilizer of the load fluctuations and vagaries of the several exciters paralleled upon the bus. In case of direct-connected exciters, standby provision is not so necessary and is frequently omitted without any great hazard. Where standby is provided for individual exciters, throwover from normal to the reserve source of excitation is sometimes accomplished automatically.

Control of excitation is much more simple with the individual exciters than if common bus excitation were employed. In the former case, only a small exciter field rheostat is necessary, whereas in the latter case a large field rheostat is required in addition to the exciter field rheostat. In either case all rheostats are regulated very satisfactorily by the station operators, according to the desirable division of energy as well as the reactive components among the various machines. This is necessary to obtain the best overall plant economy of the main units. Only in a few cases, perhaps, where the load fluctuates rapidly, is automatic regulation really desirable.

It is pointed out that for best economy every prime mover in the plant should be the most efficient machine available of its relative type, and therefore that exciter generators should drive their energy directly or indirectly from either the main turbine or an auxiliary turbine carrying the combined load of a member of plant auxiliaries. A direct-connected exciter may accordingly afford the maximum of economy as well as the major feature of reliability.

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Exciters and Systems of Excitation

BY H. R. SUMMERHAYES

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IN laying out excitation systems for central power stations continuity of service is the primary requirement. First cost and economy in operation are secondary requirments which must be given due weight.

Exciter design, method of drive, wiring and connections, method of control and reserve capacity are considerations affecting reliability.

Systems of excitation are considered under:

1. *Common Excitation Plant* (exciters operating in parallel on a bus supplying the fields of all generators.)
2. *Individual Exciters* (not operating in parallel.)

Common excitation plant has predominated in American practise for many years, while European practise has shown more preference for individual exciters. In recent years American practise has tended more and more toward individual exciters.

Of the steam turbines 7500 kv-a. and over, sold by one manufacturer during the past five years, about 45 per cent were equipped with direct-connected exciters; and of the hydroelectric generators 1000 kv-a. and over, about 75 per cent had direct-connected exciters, and an additional percentage had individual motor-driven exciters.

Common excitation plants have the chief advantage of constant bus voltage, permitting floating storage battery on exciter bus, a plan much used in important lighting stations to insure against shut-down due to excitation trouble.

With individual exciters the circuits are short and simple, and trouble with one exciter affects only one generator.

Methods of Drive are discussed for both individual and common excitation plants with the conclusion that for large plants direct-connected exciters are most reliable, efficient and less costly whenever speed requirements allow their use.

Volts Pressure of Exciter Plant is standard at 125 volts, except for large plants, when considerations of alternator and exciter design, expense of bus bars, connections, switches, etc, dictate a choice of 250 volts.

Excitation Requirements as to kilowatts and voltage range are discussed. Kilowatts required vary from 1.5 per cent down to 0.53 per cent of alternator rating. Individual exciters must operate down to 30 or 40 per cent of rated pressure. Continuous rated exciters should be chosen 20 per cent larger than stated excitation kilowatts.

Exciter Rheostats for use with voltage regulators should have resistance three to four times that of exciter field. For individual exciters rheostats should have 100 to 150 steps so as to get close graduation at the lower pressures.

Electrically operated rheostats are preferred for convenience of operation and location near alternators.

Exciter Circuit Breakers and Field Switches should be non-automatic on overload. Exciter breakers should operate automatically on reverse current and field switches automatically only in connection with balanced or reverse-current protective systems which operate the oil circuit breaker in the alternator circuit.

Electrical control is advocated for large plants, to permit location near machines and operation from main switchboard.

Exciter Batteries are installed in important stations either floating or in reserve.

Methods of charging are discussed. The control bus for electrically operated circuit breakers should be separate from the exciter bus, which is subjected to high transient voltage from the alternators in case of short circuits on the a-c. system.

Shunt Exciters are recommended for individual exciters, or for exciters operating in parallel with batteries on account of less chance of motoring and polarity reversal.

Compound Exciters are recommended for parallel operation without battery and on account of better maintenance of voltage and less rheostat adjustment required.

For operation with regulators there is little choice between shunt and compound, shunt being better when wide range or sensitive regulation is desired.

Commutating Pole Exciters for parallel operation, whether shunt or compound must have a drooping characteristic when operating without series field. For parallel operation over wide voltage range the design should be such that a slight forward brush shift may be used, in connection with a somewhat weak commutating field. With such a machine a drooping characteristic is obtained over a wide range of voltage and satisfactory parallel operation ensured, whether shunt or compound.

Voltage Regulators are not generally used in the largest city central stations on account of the proportionally small load fluctuations, excepting where such loads as steel mills or railroad electrification are supplied.

They are commonly used on hydroelectric plants where the fluctuations of load are larger and governing not so good. They can be made to take care of exciters operating individually or in parallel, with one

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or multiple regulators, up to the largest plants in use or contemplated.

Station Auxiliaries in their relation to the choice of exciter plant are discussed. The conclusion is reached that for large plants direct-connected individual exciters should be used, with emergency bus, and battery. The emergency bus should be supplied by one or more motor generators driven from the a-c. auxiliary bus supplying the other station auxiliaries. Thus the excitation is normally kept separate from the house plant or station auxiliary bus. The latter, supplied by a relatively large and efficient turbine forms a reliable supply for the station auxiliaries, with possibility of efficient heat balance in a steam plant and a reliable emergency supply for the excitation, unaffected by main bus disturbances.

Application of D-C. Generators to Exciter Service

BY C. A. BODDIE and F. L. MOON

Both of Engineering Dept., Westinghouse Electric & Mfg. Co.

THE purpose of the paper is to discuss some of the problems which arise in connection with the use of d-c. machines as exciters; such as choice, range and stability of exciter voltage ,stability of parallel operation, responsiveness, use of main rheostats, and use of compound field windings.

The choice of exciter voltage is usually not a matter of great importance; yet in some cases there are good engineering reasons for choosing 125 volts rather than 250, or the reverse. When automatic regulators of the Tirrill type are used, the exciter must be capable of operating over a range from two to one to three to one; the maximum voltage required being 10 or 15 per cent above the rated value. If the exciter has considerable cumulative series field, it may be difficult to obtain the required minimum voltage.

Where automatic voltage regulators of the Tirrill type are employed, a responsive system is necessary to avoid hunting of the regulator; otherwise the regulator main control must be damped until the whole system is very sluggish. The responsiveness of the system depends chiefly upon the quickness with which the exciter voltage responds to changes in its field resistance and upon the speed with which the alternator field current responds to changes in the exciter voltage. The time rate of change of the voltage of a d-c. machine when its field resistance is altered, is proportional to the instantaneous difference between the $I\ R$ drop in the field circuit, and the terminal voltage of the machine, that is, the "opening" between the magnetization curve and the volt-ampere characteristic of the shunt field circuit, as measured in volts: and is inversely proportional to the interlinkages of flux and field turns at rated voltage. A number of secondary factors have an influence upon the final result.

The problem of running exciters in parallel is largely the same as with other d-c. machines. Where Tirrill type regulators are used, the situation is more complicated owing to the range of voltage over which the machines must operate. There are several ways in which the drooping characteristic necessary for stable parallel operation may be obtained; and in general it may be said that in any case exciters may be made to parallel satisfactorily. Further, when automatic voltage regulation is used approximately correct load division at all voltages is ensured by making the maximum voltages the same, and making the average rate of decay of voltage about the same as the average of building up for each exciter.

Differential series windings are not detrimental to regulator performance and in some cases may be of benefit in promoting stability of parallel operation. Cumulative series windings, if they constitute a considerable portion of the total field strength may seriously impair the quality of regulation obtained. In some cases trouble from polarity reversal of compound-wound machines under abnormal conditions, has been experienced. Sufficient cumulative series to balance the demagnetizing armature reaction in a non-commutating pole machine, is not only harmless but is desirable; and is very necessary where broad range regulating is used, in order to avoid polarity reversal.

When the exciters are connected to a common bus the excitation voltage cannot be varied to suit the needs of an individual generator; and a field rheostat or equivalent device is needed. When individual exciters are used, the excitation may be controlled by adjusting the exciter field rheostat, or by means of main field rheostat or equivalent. When it is considered safe to rely entirely upon automatic voltage control, the main rheostat may be omitted entirely or reduced to a small affair. Where thoroughly dependable hand control is desired, the question of exciter voltage stability must be considered. At the lower exciting voltages, rather poor control over the exciter voltage is experienced; hence it would be desirable to have some variable resistance in the main field circuit to render unnecessary the operation of the exciter upon the straight part of its magnetization curve.

One of the two fundamental ways of improving the response of an exciter is to increase the "opening" between the magnetization curve and the volt-ampere

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characteristic of the shunt field circuit, though the possible gain is quite limited for several reasons. The other way is to reduce the number of interlinkages at rated voltage. As this depends partly upon the magnetic flux, some gain may be made by a reduction in the value of the flux. However the principal gain comes from a reduction in the number of turns; as this means a corresponding increase in the field current, the latter may require attention. The current which the shunting relay contacts can handle is limited in value, the limit lying between 20 and 25 amperes unless the block of resistance shunted by the contacts is abnormally small. If the needed reduction in the number of turns makes the field current too high, which is liable to happen if the exciter is built on a relatively large frame, the current must be split up among two or more circuits, as by winding the coils with several conductors in parallel, or by series parallel connection of the field coils.

The method of driving exciters by connecting them directly to the main units, has a definite relation to exciter design. On account of their disproportionate cost, direct-connected exciters are not often used with low-speed, small capacity units; and on account of the difficulty of building satisfactory d-c. machines for very high speeds, they are not often used with high-speed turbo-generators. For low-speed, large capacity units the exciters, if direct-connected, must be built on a relatively large frame, as a result of which they are inherently sluggish. However, they can be made very satisfactory from the voltage regulator standpoint by some of the methods mentioned above.

Exciter Practise in the Northwest

BY J. D. ROSS

Supt. of Lighting, Member Board of Public Works, Seattle, Wash.

EXCITER practise in existing Pacific Coast plants is indicated in a table giving the number and size of generators, the number and size of exciters with their drive, the manner of connection and whether a regulator is used or not, for the largest or newest hydroelectric plant of each large power company in British Columbia, Washington, Oregon and California.

Because of the difference in size and characteristics of machines whose fields are fed from the same exciter bus, and because of its complication and its tendency to pile up the voltage on a short circuit, the automatic regulator is little used in Northwestern plants.

For a new 15,000-kw. hydroelectric unit being added to the Cedar Falls station of the Seattle system, the writer chose an exciter large enough for a 36,000-kw. plant, the full final development of the entire station, so that only one exciter will be operating at a time. This design was preferred to that of an individual exciter for each generator, because of its greater simplicity especially since a regulator is to be used. The idea of simplicty is further emphasized in this plant by making the new generator and its transformer a unit, without intermediate busbars, using mica insulation, class B, throughout in both generator and transformer.

Auxiliaries are driven from an auxiliary bus energized by a prime mover and a battery, and entirely separate from the exciters, assuring a steady voltage for auxiliaries and removing a complication from the exciter system.

The same plan of excitation is followed in the new 15,000-kw. unit being added to the steam plant in Seattle, where 35,000-kw. three-unit plant will be controlled through one exciter, steam turbine and motor-driven. In order to get a large enough exciter of the proper speed, one exciter generator is mounted on each end of a shaft, with exciter turbine and motor between. In the new steam unit also the generator and transformers are connected together directly, without intermediate buses.

The writer sees no logical excuse for the compound-wound exciter; it tends to pile up the voltage on a short circuit, and to give much trouble in paralleling. The shunt wound machine with ample voltage range is ideal.

The trend on the Coast is away from small generators of different characteristics to large and uniform generating units. A number of plants are using combined waterwheel and induction-motor drive for at least one of the exciters. One company uses an exciter on each main unit shaft, each exciter large enough to supply two generators, with no added spare exciter. Another company uses the same plan but adds a spare exciter unit, driven by a motor.

The ideal exciter system for an entirely new plant is one in which each generator has its own shunt-wound exciter, driven by prime mover and having its own regulator. This allows a new generator to be ordered with its proper exciter regardless of changes in design of machines. In adding a machine to an old plant having its exciters connected to a bus, the use of one large exciter to operate the entire plant is the best compromise. The old exciters may then be used as duplicates.

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Generator Excitation Practise in the Hydroelectric Plants of the Southern California Edison Company

BY H. H. COX and H. MICHENER

Both of the Southern California Edison Co., Los Angeles, Cal.

THE writers describe the installation and operation of exciters at the generating stations and substation of the Southern California Edison Company. The system includes two 240-mile, 150,000-volt lines, which constitute probably the most extreme range of excitation of any system in operation.

The plants connected to these lines are Big Creek Power Houses Nos. 1 and 2, each with 32,000 kw. installed capacity, Eagle Rock Substation with 54,000 kv-a. installed step-down transformer capacity, Kern River No. 3 with 32,000 kw. installed capacity which will be put into operation in the latter part of 1920, and Big Creek Power House No. 8 with 22,500 kw. installed capacity which will be put into operation during 1921.

At the plants Nos. 1 and 2, each with two 17,500 kv-a. generators, there are two 150-kw. exciters respectively, one exciter of each set being also coupled to an induction motor. The exciter fields in station No. 1 are supplied from a motor-generator set, called an agitator, consisting of a 250-volt d-c. and a 125-volt d-c. machine connected in series opposition driven by an a-c. motor. The 250-volt machine is under control of a standard range Tirrill regulator controlling it from 125 to 250 volts. The resultant voltage, 0 to 125 volts, of the two machines is taken to excite the fields of the main exciters, giving them a range from 0 to maximum. At plant No. 2 the exciters are under control of a broad range regulator controlling their voltage from residual to maximum.

At Eagle Rock Substation, two 15,000-kv-a. synchronous condensers have direct-connected exciters, with one motor-driven exciter for a spare machine. The exciters are controlled by broad range regulators.

The system of operation of the existing plants starting from dead is described in detail.

In the new Kern River No. 3 power plant, with two 17,500-kv-a. generators, each generator is to be equipped with direct-connected exciters and one spare one, each of the three exciters being controlled by a separate broad range voltage regulator. In the plans for the Big Creek Power House No. 8, the initial development of which will consist of one 25,000 kv-a. unit, an exciter will be direct-connected to the generator shaft. A spare exciter will be kept at the power house, not connected to any motive power, to replace a burned out exciter on the generator in case of accident.

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REORGANIZATION OF THE EXECUTIVE DEPARTMENTS OF THE GOVERNMENT

The Joint Committee on the reorganization of the executive departments of the Government was approved by the Senate when it adopted the Smoot-Reavis resolution. The prime reason for this resolution and the thing that made its passage possible in the Senate has been the activity of engineers in their campaign to secure a National Department of Public Works.

The bill provides for study of all the Federal administrative offices by three members of the Senate and by three members of the House, who are to report their findings not later than the opening of Congress in December 1922. This committee is vested with authority to get all the evidence in the subject which is to be studied and to make definite recommendations for proper coordination to the Senate and House from time to time. It is probable that the subject of a National Department of Public Works will be the first thing taken up and since the committee can bring in their recommendations in the form of resolutions or bills at any time, it is not contemplated that this investigation will in any way hold up the progress of the Public Works campaign. On the other hand it is distinctly a recognition of the engineers work; it shows just the attitude that the leaders of the Public Works movement have been trying to instill in the leaders of Congress, namely, that there is room for great improvement and that Congress should cooperate in a whole-hearted manner to bring this improvement about.

The Senate passed the measure by acclimation after speeches favoring it had been made by Senator Smoot, who is in immediate charge of the legislation for the majority. Senator Underwood, Democratic leader, also made a speech in favor of the resolution, in which he made the following statement: "I do not understand that it is introduced by way of criticism of anything which has taken place recently or in the distant past. The conflict for authority between the various bureaus of the Government and the duplication of work has not been deliberately done, but has grown up through a period of years. That there is a vast duplication of work in the Government, that there is lost motion and lack of economy cannot be questioned, and I think an effort should be made to avoid duplication and to work toward greater economy in the Government."

The 150,000-Volt Transmission Line of the Knoxville Power Company

BY THEODORE VARNEY

Aluminum Company of America, Pittsburgh, Pa.

AT a point on the Little Tennessee River a short distance above the mouth of the Cheoah River in North Carolina, the Knoxville Power Company has completed within the past year, the first portion of an extensive hydroelectric development. The ultimate development will require the tying together of a number of plants scattered over a large area and it was therefore necessary to choose powerhouse and transmission line equipment which would be best adapted to the entire system.

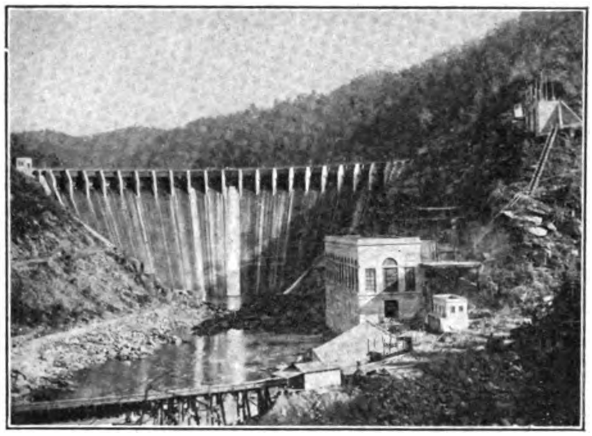
The initial development described herein might appear inconsistent if considered alone from the standpoint of voltage and length of line, but when regarded as an integral part of the larger scheme its characteristics become rational. For instance, the present line crosses a mountainous country, broken by river valleys and steep cliffs for about half its length, while the remaining distance lies over a fairly level plain. The rough ground necessitating a minimum number of supports required that a maximum amount of power be carried by each circuit and this in general means a high transmission voltage. It is probable that in choosing between a voltage of 110,000 and 150,000 the former would have sufficed for the present line, but as the complete development will involve lines of greater length, the higher voltage would have later become necessary and a uniform voltage for the system was considered essential.

Another point taken into account by the engineers who were responsible for the present design was that the trend or development is toward the use of higher voltages for transmission lines.

Still another consideration which made it advisable to provide for high efficiency, and consequently small losses, is the high load factor of the electrolytic process for which the system is primarily designed. Power for this purpose is valuable and interruptions are very expensive.

The electrolytic plant is located at Alcoa, Tennessee, formerly known as North Maryville, and its distance along the line from the present power house at Cheoah is 24.3 miles. At present one line only is completed between these points but ultimately another parallel line will be provided, and these will later be joined by additional lines supplied from other plants.

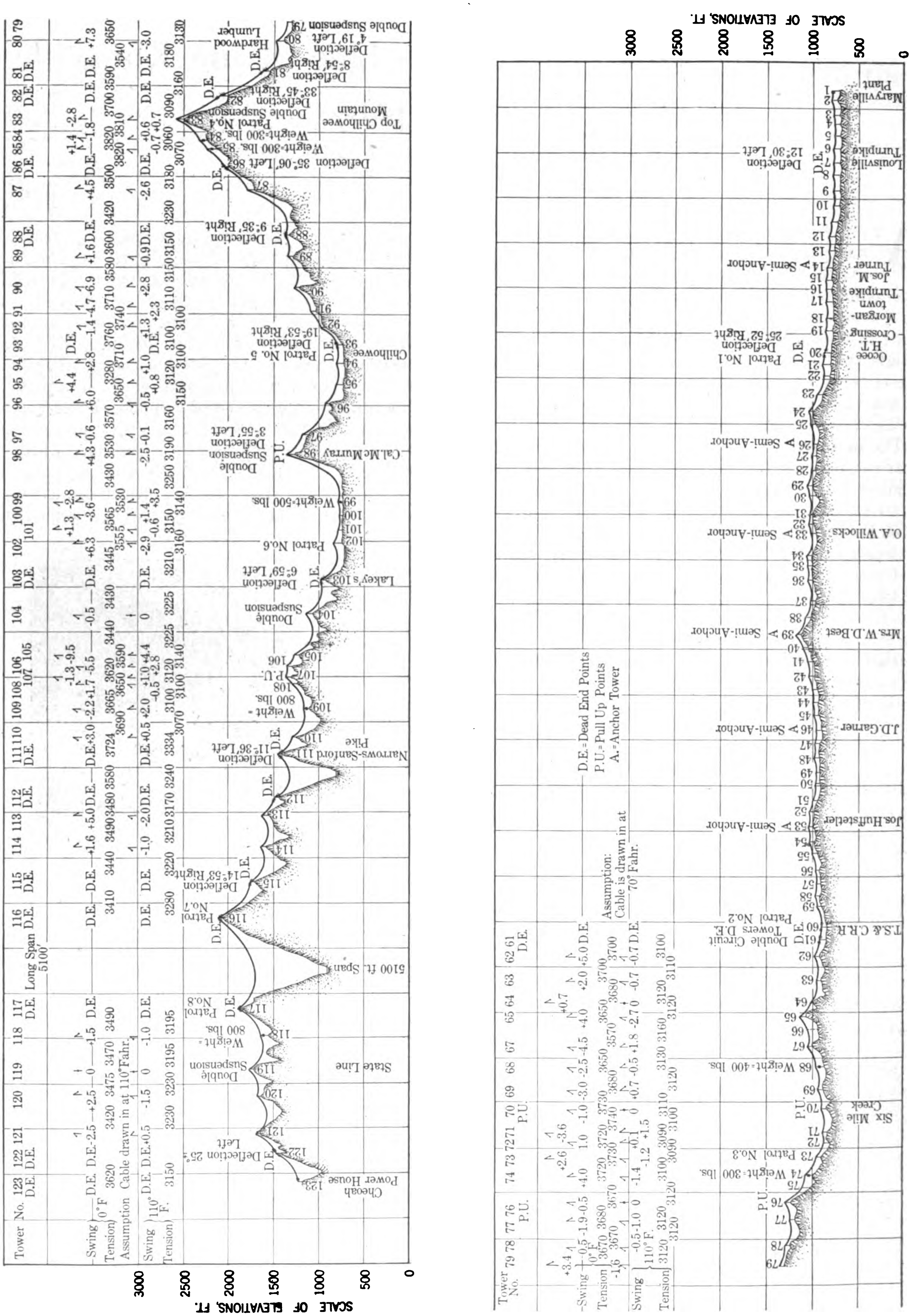
The broad scheme of development contemplated for the entire system is to operate it normally in units of about 50,000 h. p. so that the interruption due to a short circuit or other trouble anywhere on the system will not cause any disturbance or interruption outside of this group of 50,000 h. p. With this idea in view, the power houses contain no low-tension buses. Each of the generators (most of which will be about 20,000 kv-a. capacity) is served by a bank of transformers connected directly to it through low-tension switches, the high-tension side of the bank of transformers being connected to the high-tension bus through a set of oil switches. The high-tension bus at the powerhouses is sectionalized in such a manner that in normal operation a group of two of these generators with their transformer banks is connected to it and this group serves a transmission line, which terminates in a section of high-tension bus at the receiving end at Alcoa, which through step-down



DAM AND POWER HOUSE AT CHEOAH

transformers, serves an electrolytic load of about 50,000 h. p. The high-tension buses at the generating station and the high-tension buses at the receiving station are so arranged that they can be interconnected whenever emergency makes it necessary to run them in multiple, but it is intended that in normal operation the system shall be operated in units of about 50,000 h. p. consisting of a suitable amount of generating capacity and step-up transformers delivering power over an individual circuit to a suitable sectionalized load at the receiving end.

The right-of-way at the Alcoa end is 385 ft. wide and provides for four double-circuit tower lines. As the rough country is approached some of the lines branch off and the right-of-way narrows to 340 ft. to accommodate four single-circuit tower lines while still further along, the width is decreased to 200 ft. for the two



Profile of 150,000-Volt Line

remaining single circuit lines which will connect with the present plant at Cheoah. The right-of-way purchases include tree trimming rights fifty feet on each side and outside of the entire right-of-way. A telephone line on wood poles is provided for along each side of the right-of-way, one of which is at present completed.

The span lengths in the level country are fairly uniform and not over 800 ft., but in the mountains hardly any two spans are alike and several are over 2000 ft., while at one point where the line crosses the gorge of the Little Tennessee River, the span length is 5010 ft. The average span length for the entire line is more than 1200 ft.

The greatest altitude at any point in the line is about 2100 ft. and the corona is not, therefore, a serious item. However, on account of the high voltage, a considerable diameter for the conductor is desirable and it was furthermore necessary to use one having ample strength in order to meet the conditions imposed by the long spans and rough country. Accordingly, the conductor consists of aluminum reinforced with high grade steel which provides minimum weight with maximum strength. It was furthermore thought best to provide for carrying the entire load of the Cheoah power house on one line in case of emergency.

After the completion of the line and just before it was put into service in March, 1919, it was short-circuited at the powerhouse and current corresponding to 37-500 kw. and 75,000 kw. respectively, at 100 per cent power factor, was supplied at the receiving end from a steam turbine plant, with the following results.

Amps.	Volts.	Kw.	Frequency	Power Factor	Line loss
144	5160	330	60	25.6	0.885% of full load
288	9720	1230	60	25.4	1. 65% of double load

Temperature air at power-house 18.0 deg. cent.
Temperature air at receiving end 13.5 deg. cent.

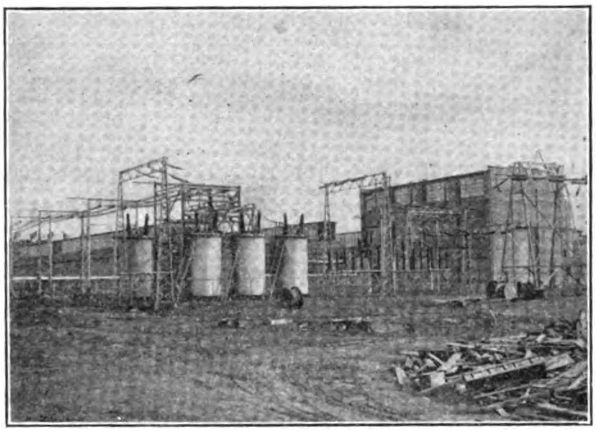
Hydraulic Plant

The dam of the present development is of reinforced concrete approximately 500 ft. long on its up-stream face, extending across the rocky gorge in the Great Smoky Mountains, through which the Little Tennessee winds its way westward to join the Big Tennessee. The crest of the dam is approximately 177 ft. above normal tail-water elevation, while by means of Taintor gates the pool level can be raised about 15 ft.

A tunnel about 540 ft. long driven through the rock in the left bank of the stream, discharges into a surge tank, also excavated in the rock, from which four tunnels lead sharply downward to the turbines in the powerhouse.

Power House

The power house which is constructed of reinforced concrete, approximately 216 ft. long, by 61½ ft. wide inside, provides for four generating units, of which three are installed at the present time. These are of the vertical-shaft type operating at a normal speed of 171½ rev. per min., and capable of delivering 20,000 kw. at 13,200 volts, three-phase, 60 cycles. Each feeds directly through a three-pole, 1200-ampere, automatic, inverse-time-limit, oil circuit breaker to a bank of three 7000-kv-a. single-phase, transformers stepping up to 150,000 volts. The high-tension side of these transformers are operated in star with neutral grounded and are connected to a high-tension bus, to which at present is connected through choke coils, one three-phase transmission line. Provision is made in the outgoing line for the future installation of a 150,000-volt oil cir-



Receiving Station at Alcoa, Tenn.

cuit breaker. Electrolytic lightning arresters are provided, and arc suppressors equipped with eight automatic fuses per phase are being installed.

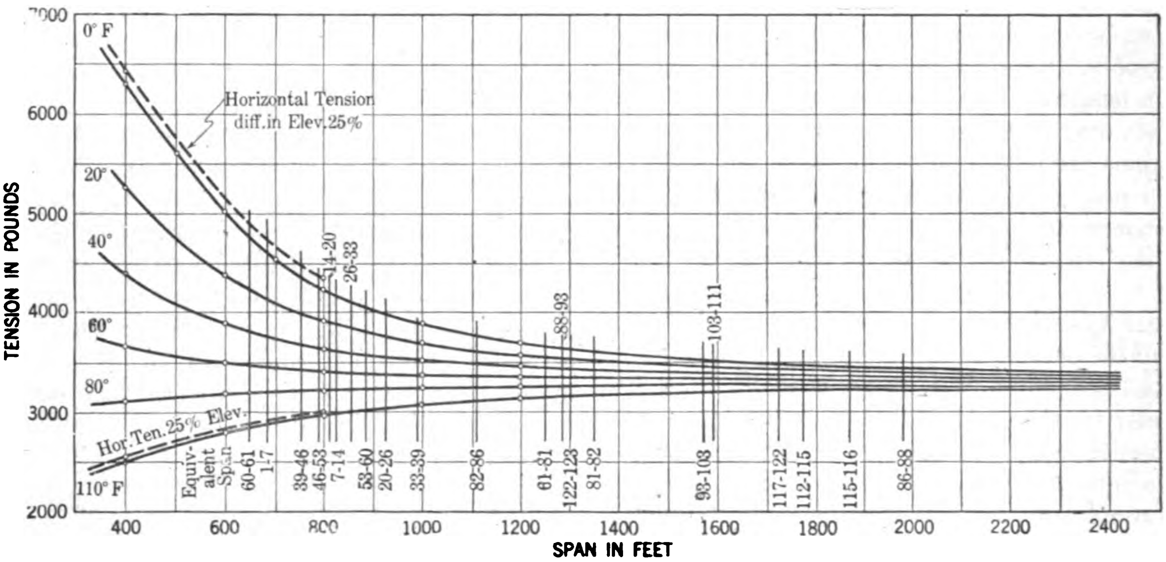
At Alcoa, the line connects directly through choke coils to a bank of three 14,000-kv-a. transformers, stepping down to 13,200 volts. Electrolytic lightning arresters are provided and provision is made for the future installation of an automatic oil circuit breaker on the line side. The low-tension side is connected through disconnecting switches and a 3000-ampere automatic oil circuit breaker to a 13,200-volt bus system to which are connected through disconnecting switches, oil breakers and transformers, twenty 2500-kw. synchronous converters. These converters deliver 500 volts d-c. to a 24-hour electrolytic load.

Transmission Line

The conductor decided upon is a 500,000-cir. mil aluminum cable, steel reinforced, the details of which are given with other data at the eud of this paper. The maximum tension in the conductor was not taken at the full elastic limit, but at 8000 pounds for the reason that in previous installations of somewhat similar character it had been found that greater tensions re-

quired a greater cost for tower construction and a preliminary investigation in the present case indicated this tension to be sufficient.

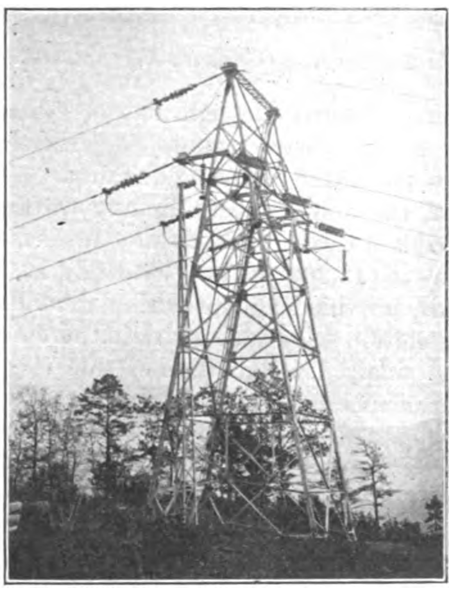
ice or wind was computed. This gave a value of approximately 3300 pounds. From this value the unloaded tensions for every 20 degrees from 0 to 110 were



Conductor Stringing Curves

It was assumed that this maximum tension would occur at 0 deg. fahr. with one-half inch of ice all around the conductor and a wind pressure of six pounds per square foot of projected surface of ice-covered cable.

By carefully studying the profile of the land the dead end and semi-anchor towers were located in such manner that the equivalent values of the spans between any

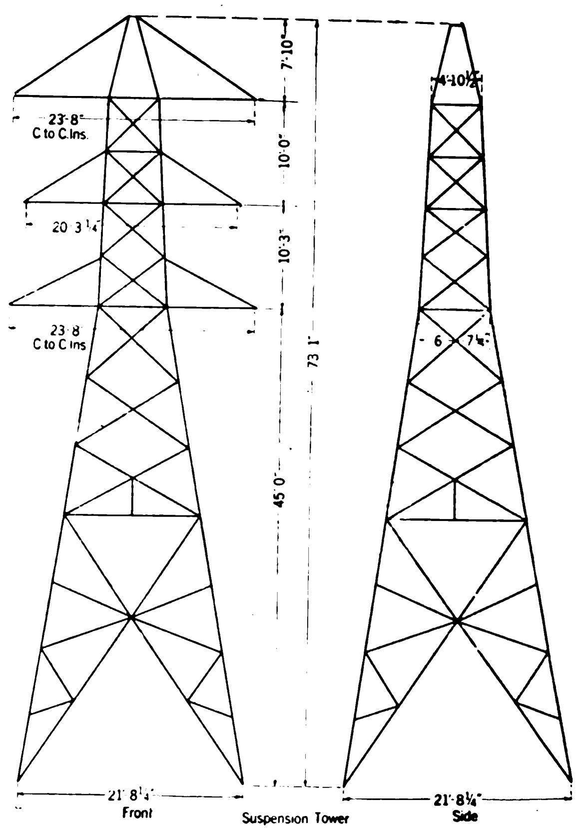


Long Span Anchor Tower

two anchor points, as referred to level supports, would not be very widely different. By this means the shortest equivalent span was found to be 650 ft. and the longest (exclusive of the 5010-ft. span which was treated separately) 2400 ft.

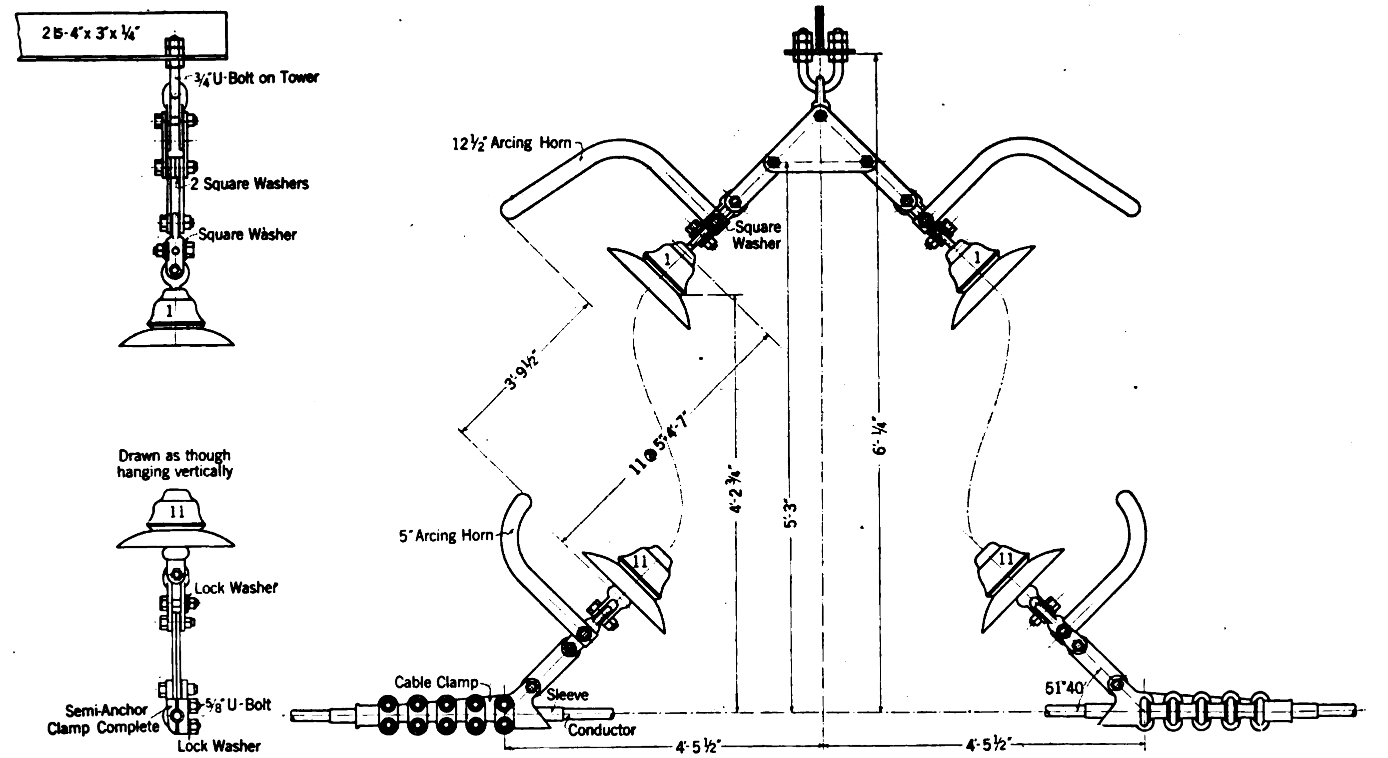
From the condition of maximum load in the shortest span, the tension corresponding to 70 deg. fahr, without

calculated for the ruling equivalent span for each of the consecutive dead end sections of the line. These curves are given in one of the illustrations. The equivalent



span numbers refer to the tower numbers in the profile, which is also illustrated.

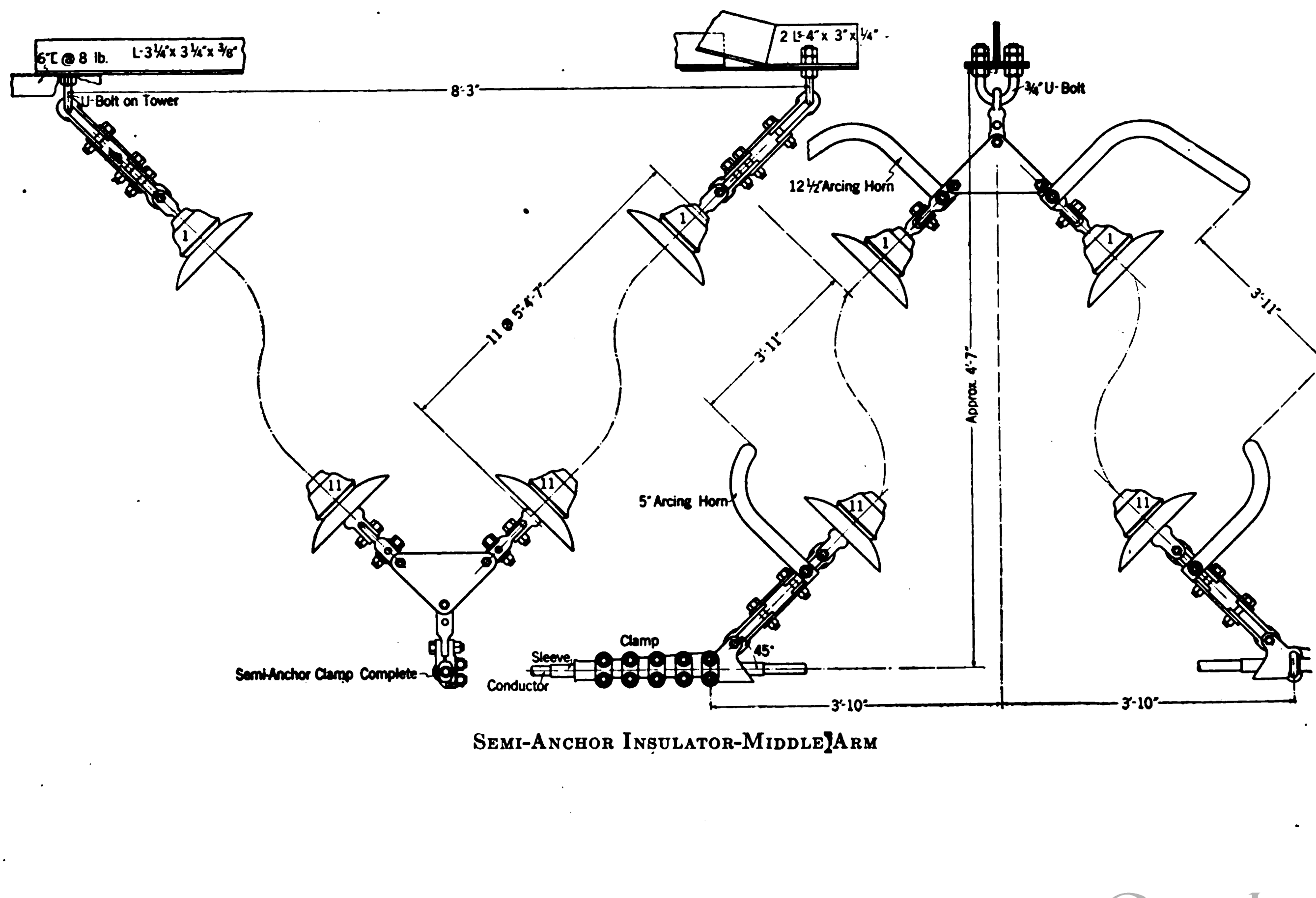
The cable was strung out through travelers and pulled up to the tension given in the curves corresponding to the stringing temperature. The insulator strings



SEMI-ANCHOR INSULATOR ASSEMBLY—TOP AND BOTTOM ARM

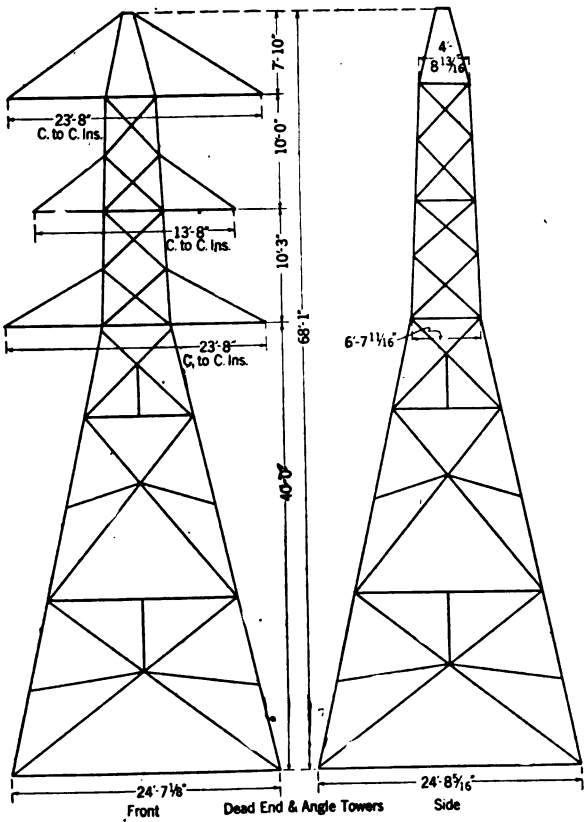
were hung vertically under these conditions but as the adjacent equivalent spans in each anchor section were not equal, any temperature changes produces a swing from the vertical in the insulator strings. A study was made of this condition and the position of the insulators was calculated for 0 deg. and 110 deg. fahr. The profile indicates the right and left swing of the insulators at the various towers in the rough country, corresponding to those extreme tempratures, assuming the strings to be vertical at 70 deg. fahr.

The towers were constructed of galvanized steel, delivered on the ground in sections and bolted together. As stated above the towers in the level country were double-circuited and in the mountains single. The illustrations indicate the several types of towers, together with the extensions used on rough ground as

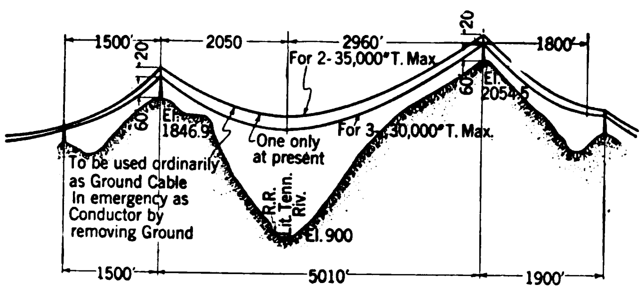


SEMI-ANCHOR INSULATOR-MIDDLE ARM

well as the anchors. The approximate weight of a double circuit suspension tower is 12,900 pounds and that of an anchor tower 13,200 pounds. The single circuit suspension tower weighs 11,200 pounds and the anchor tower 13,100 pounds.



Calculations were made of the side sway assuming wind pressures of 19 pounds per square foot on bare cables, and in order to provide proper clearance from the tower arms, brackets were provided to which the insulator strings are attached. These brackets, which

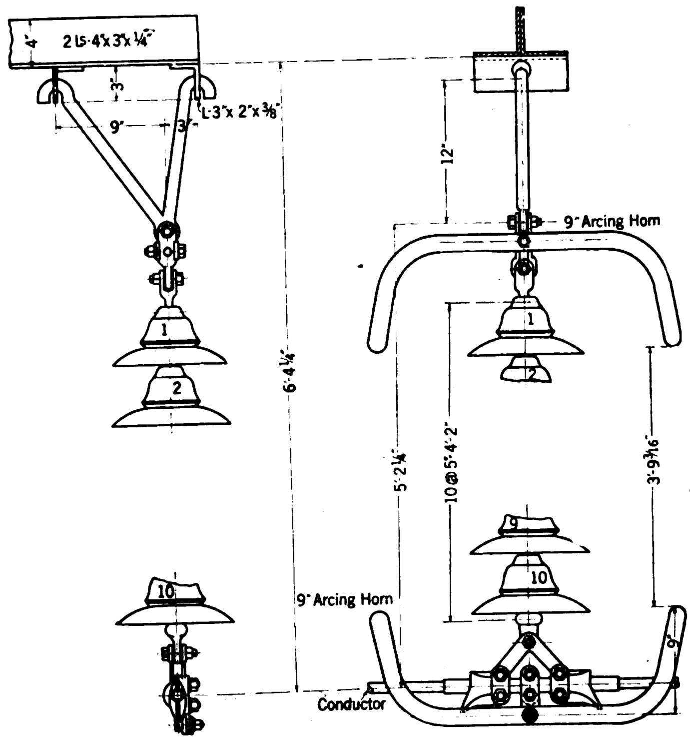


ELEVATIONS AT LONG SPAN

appear in the illustration, were hinged so as to prevent applying excessive torsional stresses to the bracket arms in case of a broken conductor.

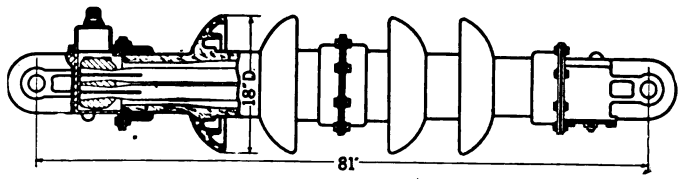
In addition at certain points where towers are located on side hills, the cable weight on the suspension strings is reduced in cold weather. While actual uplifts are provided against at these points, the tendency for side swing is increased and to overcome this, weights were attached to the insulator strings. This construction is shown in the illustrations and the towers where this construction was used are indicated on the profile.

Where the weight of unusually long spans has to be carried by suspension insulators the strings are doubled,



SUSPENSION INSULATOR ASSEMBLY
Top and bottom arm, two-circuit tower; all supports, one-circuit tower

while on the middle arms of the double-circuit towers double strings of insulators are used to prevent side sway and to enable a short arm to be used. This arrangement obviated placing all three phases in a vertical plane and enabled the bracing members of the



STRAIN INSULATOR AT LONG SPAN

tower to be reduced in weight, while still providing ample strength to resist torsional stresses due to a broken conductor.

At present one ground wire consisting of a ½-in. galvanized, high-strength, stranded steel cable is provided throughout the line except at the long span where special arrangement is provided as described later. Provision is made on the towers for adding a second ground wire if desired. The stringing tension for the ground wire was 2700 pounds at 70 deg. fahr.

One of the illustrations shows the relative elevation of the supports for the long span, compared to its length. The horizontal distance between supports is 5010 ft. while the difference in elevation is 208.5 ft.

The temperature at the time of stringing the cables was about 80 deg. fahr. and the three lower cables were strung with a sag of 237 ft. below the lower support, corresponding to a tension of 19,000 pounds per cable. The upper cable was installed with a sag of 216 ft. below its lower support and with a tension of 20,400 pounds. The horizontal separation between the lower conductors is 20 ft. and the upper cable is 20 ft. above the lower three at the points of support.

One of the long span towers, marked *W* in the illustration weighs 55,000 pounds and the other *W W* weighs 57,000 pounds.

In these spans the steel core of each cable carries the entire load and the cores are socketed with zinc into open forged steel bridge sockets which are attached directly to the strain insulators. The aluminum part of the cable is cut off in advance of the sockets and connection is made by means of an aluminum parallel groove clamp and jumper connection to the other side of the tower.

Each cable is provided at each tower with a single 150,000-volt, oil filled, porcelain covered, wood strain insulator. In deciding to use this type of insulator the engineers were guided by the previous satisfactory performance of similar insulators on a 110,000-volt river crossing belonging to the Tennessee Power Company. Very careful and complete tests were made of the insulators before installing, and in order to provide a spare part in case of a strain insulator breakdown the upper conductor of the long span was arranged to be normally grounded, thus replacing the standard ground wire. A busbar arrangement is provided so that this conductor may be substituted for anyone of the three conductors, which may then be grounded and repaired. One of the cuts illustrates the construction of the strain insulators.

This span, which is understood to be at present the longest single conductor span in the world, involved cable lengths too heavy to be readily transported to either tower and consequently a rather ingenious scheme was employed for installing them. They were wound at the factory on special reels having a partition which divided the total amount of the cable into two parts, each of proper length to reach from the railroad at the bottom of the gorge to one of the towers.

The reel was set up beside the railroad track and a portion of the long section pulled out first. When the portion of this section still remaining on the reel equalled the short section, the latter was started out. The ends arrived at the towers at the same time and the loop was removed from the partition in the reel without damage or splicing. The cables were pulled to tension with a donkey engine.

There are eight patrol stations provided along the telephone line on the right of way. The location of each is indicated on the profile. Two patrolmen are constantly employed. One covers the line from Alcoa to Patrol Station No. 4 at Tower No. 83, while the other inspects the line from Tower No. 83 to the Cheoah Power House.

The latter covers the rough country from Cheoah to Patrol Station No. 7 at Tower No. 111 on foot and over the balance of the distance to Tower No. 83 he rides horse-back. Each patrolman goes over the line once every week and in addition makes an inspection after any storm or lightning interference.

CONDUCTOR

The conductor consists of aluminum cable steel reinforced composed of a double galvanized extra high strength steel core, overlaid with strands of hard drawn aluminum.

The elastic limit and ultimate strength of the aluminum strands are respectively 14,000 and 24,000 pounds per square inch.

The corresponding values for the steel core are 130,000 and 160,000 pounds per square inch. The elastic limit and ultimate strength of the complete cable is taken as the sum of the corresponding values for the individual strands.

The modulus of elasticity of the aluminum portion of the cable is taken at 9,000,000 pounds per square inch and of the steel portion 30,000,000 pounds per square inch.

The characteristics of the conductors are as follows:

Standard Conductor	
Steel	19 x 0.0775 in.
Aluminum	30 x 0.1291 in.
Diameter complete cable	0.904 in.
Weight per foot complete cable	0.776 lb.
Elastic limit complete cable	17140 lb.
Ultimate strength complete cable	23750 lb.
Weight of ice per foot (½ in. thick)	0.859 lb.
Wind pressure per foot (6 lb. square ft. over ice)	0.952 lb.
Resultant, loaded weight per foot	1.892 lb.
Wind pressure per foot (19 lb. square ft. on bare cable)	1.43 lb.
Resultant, loaded, weight per foot	1.625 lb.
Virtual coefficient of expansion per deg. fahr	0.00001003
Virtual modulus of elasticity	12,900,000 lb.
Long Span Conductor	
Steel	61 x 0.097 in.
Aluminum	22 x 0.150 in.
Diameter complete cable	1.175 in.
Weight per foot complete cable	2.032 lb.
Elastic limit complete cable	65,000 lb.
Elastic limit steel portion	59,000 lb.
Ultimate strength complete cable	82,000 lb.
Ultimate strength steel portion	73,000. lb.
Weight of ice per foot (½ in. thick)	1.025 lb.
Wind pressure per foot (6 lb. sq. ft. over ice)	1.085 lb.
Resultant, loaded weight per foot	3.25 lb.
Wind pressure per foot (19 lb. sq. ft. on bare cable)	1.86 lb.
Resultant, loaded, weight per foot	2.75 lb.
Virtual coefficient of expansion per deg. fahr	0.0000077
Virtual modulus of elasticity	20,200,000 lb.

INSULATORS

It was realized that carefully selected porcelain with working mechanical tensions limited to safe values would be necessary to insure successful operation and, accordingly, the following points were covered by the specifications when the standard suspension and anchor insulator units were purchased:

Porcelain bodies to be non-absorbent, thoroughly vitrified, free from cracks, etc., and surfaces in contact with cement to be unglazed.

Caps to be of galvanized malleable iron of minimum ultimate strength of 30,000 pounds per square inch and designed for a maximum stress of 12,000 pounds per square inch at 9500 pounds total load.

Pins to be of soft steel drop forgings designed for a maximum stress of 35,000 pounds per square inch at 9500 pounds total load.

Parts to be cemented together with slow setting neat Portland cement of best quality.

Porcelain parts taken from kiln to be subjected to dry flash-over test for five minutes. Five days after cementing and before six days, units to be subjected to 3500 pounds load for five minutes. Units to show puncture voltage under oil of at least 120 per cent of dry flash-over voltage. Ultimate tensile strength of complete unit to be not less than 8500 pounds. Resistance of units to be infinite when tested with 1000-volt, 2000 megohm megger. Standard A. I. E. E. wet flash-over test for complete string of ten units to be not less than 390,000 volts at 60 cycles.

For the long span strain insulators the following points were covered by the specifications;

Tension members to consist of selected hickory and be able to stand before assembly a tension test of 25,000 pounds for one-half minute, also a dry flash-over test of 520,000 volts.

End castings before assembly to be able to stand a load of 75,000 pounds.

Complete insulator to stand load of 35,000 pounds for one-half minute, a temperature of 140 degrees fahrenheit for five hours without leakage of oil and after cooling a test of 520,000 volts.

Power was first turned on this line April 16th, 1919, and to date (February 1920) no interruptions due to any defects of the line have occurred.

The writer is indebted to Messrs. William Hoopes, T. J. Bostwick, I. G. Calderwood, L. W. Henry and B. F. Grote for the data included in this paper.

ARMY PAY BILL AFFECTS SOME CIVILIAN ENGINEERS

When the Army Pay Bill was made law, it carried a provision whereby some of the officers of the Coast & Geodetic Survey are to receive the same pay and allowance as prescribed for officers of the Navy with whom they hold relative rank, as prescribed under act of May 22, 1917, the provisions of which were made to apply to officers of the Coast and Geodetic Survey. The bill which recently became law provides for the personnel of the Army, Navy, Marine Corps, Coast & Geodetic Survey, Public Health Service and the Coast Guard.

Actual increase in compensation ranges from about $720 to $2,700 in the various grades, which includes all the allowances granted by the bill. The officers in the Coast & Geodetic Survey feel that this is a remarkable recognition of civil engineers of the Government, and it is contemplated that it will enable them to fill up many vacant positions in that service, as a result of which, they will be able to more nearly carry out their program in the development of magnetic surveys, traverse and leveling, precise and secondary triangulation. In this connection it is interesting to note that about forty vacancies now exist in the lower grades in the officered personnel, due to the fact that civil engineering graduates have not been attracted by the old pay. The entrance salary will now be slightly in excess of $2000, which will attract more civil engineering graduates to this service.

In addition to the possibility of improved conditions in personnel of the Coast and Geodetic Survey, it is probable that the Sundry Civil Bill has passed by the House will finally contain an item for magnetic and geodetic surveys in Alaska appropriating $147,000. About $28,000 of this sum will be devoted to the magnetic surveys of the country and the balance will be expended on precise and secondary triangulation, traverse and leveling. This appropriation is the same as was available for the fiscal year 1920, except that last year's appropriation was made up of a regular appropriation of $100,000 plus a deficiency appropriation of $47,100. This compares with $90,000 available in 1919, and represents an increase of 63 per cent over the period of two years. Officers of the Coast and Geodetic Survey have expressed the opinion, however, that even with this substantial increase, there is not as much money available as will be needed in order to carry the control surveys well ahead of the detailed topographic mapping program.

Factors Controlling the Design and Selection of Suspension Insulators

BY W. D. A. PEASLEE

Electrical Engineer, Jeffery-Dewitt Insulator Co.

A discussion of the factors entering into the design and operating behavior of suspension insulators and the problems to be solved in designing a suspension insulator to overcome the objectionable features shown by experience to affect seriously the operation of the insulators in service.

Factors to be taken into consideration in the selection of suspension insulators for a given condition are given and a brief discussion of the general trend of future improvements is presented.

Introduction

IN the early days of electrical distribution of power the insulator problem was unimportant. The insulator gave more satisfactory service than the rest of the apparatus essential to the generation and distribution systems. As long as the voltages were low the dielectric field distribution was of relatively small importance. As the transmission distances and therefore the economic transmission line voltages increased the insulator problem became more acute. The first attempt to meet the insulation requirements of these higher voltage lines was an increase in the physical dimensions of the lower voltage type of unit. No attention was given at this time to the distribution of the dielectric field or its shape although the laws governing the dielectric flux distribution in such cases were well-known.

As a result with the increased voltages came an increasing amount of insulator trouble until when the transmission voltage passed the 30,000 volt mark, the insulator problem became of greatest importance. Improvement in design through rational study of the problems had brought the reliability of other parts of the transmission and generating systems to a very satisfactory point. The insulator, however, had not made a corresponding advance and failures were encountered at a rate that for a time threatened the success of high-voltage transmission of electrical energy.

The attention of the insulator manufacturers was turned at once to the problem and many new designs were brought out as suggested remedies for this situation. Practically none of these was based on a rational study of the insulator as a dielectric problem, most of the improvements being made from the narrow standpoint of the small experience then available. The problem was attacked by manufacturers and research men of the country, but unfortunately from widely different points of view. The manufacturers being limited by manufacturing difficulties and the great cost of a radical change in methods, clung to small changes in existing forms and processes, while the research man attacked the problem from a scientific standpoint, based on a careful study of the dielectric and mechanical problems involved, but too often handicapped by a lack of knowledge of manufacturing processes and their limitations. For these reasons many excellent ideas coming from both sources were laid aside from lack of coordination of the two lines of study.

In the early insulator types, at times the flash-over distance was much greater than warranted by the thickness of dielectric and many failures by electric puncture were encountered, also the design was such that corona was formed at different places on the insulator at low voltages.

Gradual improvements in the design eliminated many of these objectionable features one by one, and improvements in manufacturing methods brought forth constantly improving grades of porcelain.

When the pin type insulator reached a limit set by size, weight and cost, the suspension type unit was introduced. This was a decided step forward in insulator practise, but unfortunately the designers of the suspension type unit still neglected a thorough consideration of the dielectric field of flux in the designing of their units, making them simply mechanical modifications of the existing types.

Thus a great many faults of the early pin type insulators were repeated in the first suspension units. Due to its small size the flash-over voltage of the suspension unit was practically always below the puncture voltage, though, as will be shown later, the margin was not sufficient, and, with the introduction of the electric tests on assembled units in the factory, very few direct puncture failures were encountered when the insulators were first placed on the line.

At this point, however, a type of failure appeared which may be classified as a deterioration failure, the insulator passing successfully severe factory tests, but failing after a period of service on a transmission line under conditions less severe than those successfully resisted in the course of factory testing.

The study and analysis of this problem has filled the pages of engineering literature during the past ten years and many divergent theories regarding the causes of and remedies for the various types of failure have been advanced. At the present time insulators successfully passing factory tests deteriorate in service at rates varying up to 20 per cent per year. As stated by a prominent transmission engineer quite recently:

"All insulators at present on the market seem to be

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subject to a steady depreciation that is too large to be ignored or accepted as an operating necessity."

The conventional type suspension insulator unit, and also, to some extent, the multi-shell pin type unit, seem in general to be subjected to the types of failures indicated in the following table:

MECHANICAL FAILURES

a. Due to the use of materials having widely different coefficients of cubical expansion as in conventional cap and pin construction which causes enormous stress under temperature changes.

b. Due to mechanical overloading.

c. Due to shocks as shooting.

d. Due to lightning and power arcs.

ELECTRICAL FAILURES

a. Actual electrical puncture.

b. Leakage under adverse conditions followed by flash-over and heavy power arc.

c. Due to porosity.

In the conventional type of insulator three materials, porcelain, cement and steel, are tightly compressed in contact in an unyielding fashion. These materials have different coefficients of cubical expansion and the temperature variations, in many cases quite abrupt, met with in operation, seem to set up internal stresses which crack the porcelain, leading to electrical failure. Further the cement itself is subject to volumetric changes somewhat of cyclic nature and also of a crystalline growth character that contribute to these phenomena. Prominent engineers have expressed the opinion that 85 per cent of the failures of insulators of this type were preceded by mechanical failures of this class. The sun striking upon insulators on a frosty morning has in many cases been the signal for some rather startling exhibitions of such failures. In connection with this, the internal stresses existing in the porcelain parts due to improper manufacturing methods and firing, have doubtless contributed to this condition. That the manufacturers recognize this weakness is well shown by the elaborate precautions that have been taken to reduce this effect through the medium of felt washers, lead thimbles, etc., appearing more recently in their designs.

That the transmission engineers of the country have realized the importance of the deterioration type of failure is indicated by the extensive study, which has been made of the various methods of testing employed by most engineers responsible for large transmission systems today, such as the megger and buzz stick methods. Reliance is placed on these methods, to detect the beginning of this deterioration permitting the removal of the affected insulator before it has dangerously weakened the string. Many engineers are also advocating the deliberate addition of several units to an insulator string above the number required for actual insulation purposes as an insurance against this deterioration regarded by them as inevitable.

Failures due to mechanical overloading are rare in modern lines as the lines are usually designed with proper consideration of extreme loading conditions and ample mechanical safety factors. The same remark may be applied to failures from shock and shooting, and although at one time about the most popular outdoor sport, in certain localities, for irresponsible people, was the shooting off of the power company's insulators, fortunately, this condition is no longer of very great importance. The failures due to lightning and power arcs are, however, at the present time rather large. It is doubtful if we could define exactly what might be considered a direct stroke of lightning, and probably such strokes on transmission lines are rather rare. Lightning flash-over of an insulator string is usually in itself rather harmless, but the power arc that follows the static flash-over is extremely destructive to any but the most substantial types of insulator. The thinness of the porcelain part of the conventional type insulators, combined with the abrupt changes in form and surface directions renders them susceptible to destruction under the action of the intense heat of such an arc. Any insulator with thin petticoats is very likely to be considerably damaged by power arcs as the temperatures and the mechanical stresses involved are very high. The chief requisite for an insulator in this regard is strength, gradually increasing thickness from the edge of the skirt inwards, and a high thermal capacity. Insulators so designed will successfully resist severe power arcs and lightning surges, especially when the system is equipped with the proper kinds and numbers of relays, to a remarkable degree.

An actual electric puncture is probably rare on any modern insulator that has been properly fired, most electrical failures being the result of previous mechanical failures.

Leakage is a problem that is to a large extent dependent upon localities and specific conditions. Smelter fumes, salt fogs, dust storms and many other causes tend to make the leakage effect vary and it has been generally conceded that in bad localities the only remedy is a periodic cleaning of the insulators. A few extra units added to a string will postpone the inevitable cleaning, but it is probably safe to say that under bad conditions no insulator string could be used commercially that would not require cleaning after a time. In connection with this, however, as leakage always culminates in a flash-over, it is important that the insulator be able to withstand power arcs, especially in regions subject to bad leakage conditions.

Porous porcelain absorbs moisture from the atmosphere, thereby decreasing its electrical resistance. The leakage current flowing through the porcelain under electrical stress tends to heat localized portions to a very high temperature. This local heating causes mechanical failure followed by the passage of a power arc through the porcelain, or due to the negative temperature coefficient of electrical resistance of porcelain, the leakage current may under certain conditions gradually increase with a concomitant increase of temperature, this action being cumulative until the porcelain is punctured. A good many instances of failure

of this kind both in laboratories and under field conditions have been encountered. Good glazing postpones the deterioration of porous porcelain but cannot eliminate it.

Until recently the progress in the manufacture of suspension type insulators has been rather largely along certain detailed attempts at the improvement of certain specific faults such as the utilization of felt washers, lead thimbles, etc. in the conventional cap and pin type design. The problem had not been attacked from a sufficiently scientific standpoint and there is still great need of a scientific study of this problem based on an analysis of the dielectric field of flux around insulator strings, and the electrical and mechanical requirements of the units in relation to the limitations imposed by ceramic and manufacturing conditions.

The following discussion of the analytical and experimental work undertaken along this line from the electrical and ceramic standpoint, the progress that has been made and the results that have been secured in the form of rationally designed insulators will, it is hoped, be of some interest to the operating engineer and stimulate further study and advance in this vital subject.

Factors Governing Rational Insulator Design

The requirements to be met in the design of suspension insulators may be broadly classed under two headings:

1. The insulator must support the line mechanically with adequate safety factors under the most adverse conditions.
2. The insulator must insulate the line with adequate safety factors under any electrical conditions not rendering other apparatus on the line inoperative.

It is obvious that any suspension insulator must be designed in the form of a unit that will meet widely divergent conditions. That is, from the manufacturing standpoint it is inadvisable to manufacture units of different mechanical strengths for different weights of conductors and climatic loadings. The design hinges then upon a unit that in the heaviest lines considered under the most adverse conditions of loading will give an adequate safety factor and will yet be cheap enough to be used on the less important lines.

The insulation afforded is obtained by building up strings of different lengths, but it is hardly advisable to attempt to insulate a line at great expense to withstand almost infinite voltages when, due to the limitations of other apparatus connected to the line, the system will be inoperative under extreme over-voltage conditions.

A study of existing lines and the probable limitations in conductor sizes and tower spacing of lines from 150,000 volts down, indicate that a mechanical strength of from 9000 to 10,000 pounds is adequate for a suspension unit, provided the unit is so designed that repeated stressing does not injure the unit electrically. The rational design herein discussed is, therefore, based on this mechanical strength requirement. The amount of discussion that has taken place recently regarding the use of porcelain in compression and tension makes it advisable at this point to discuss this matter a little in detail. The mechanical strength of ordinary porcelain in tension is in the neighborhood of 1500 lb. per sq. in., while the compressive strength is around 40,000 lb. in a porcelain having reasonable dielectric and temperature change resisting qualities. On account of the wide differences in these two figures many engineers have been dubious of the advisability of using porcelain in tension. The same argument might be used against the employment of cast iron in tension, and yet, although having very largely the same mechanical characteristics as porcelain, cast iron is consistently used in tension in the design of machines and structural members. As long as the unit stresses in the material are kept below the ultimate strength of the material with due regard to adequate safety factors, there is no rational objection to the employment of porcelain in tension any more than there is to a corresponding utilization of cast iron.

Insulator Shape as Affected by the Dielectric Field of Force

The dielectric field of force between similar electrodes is in general an ellipsoid of revolution though this is not strictly true, except between electrodes which are confocal hyperboloids of revolution, and no insulator electrodes are of this form. The agreement of the dielectric field with the ellipsoid is only approximate. However, the insulator should in general be symmetrical and conform as far as possible to the shape of the dielectric field. The placing of dielectrics of different specific inductive capacitances in series should be avoided, and therefore, the surface of the insulator should follow as closely as possible the lines of force in the field. In general the equipotential planes between the insulator electrodes should intersect for equal increments of potential, equal zone widths on the insulator surface. In connection with this point it is interesting to study Fig. 1. In this figure it will be noted that the conventional type unit does not conform to this requirement and the result of this lack of conformity is the appearance of corona on the unit at relatively low voltages, the corona appearing first where the equipotential planes are closest together. The requirement of a symmetrical shape introduces at once the problem of attaching the hardware to the porcelain in a different manner from that employed in the conventional insulator type. At the same time it becomes necessary to develop some form of hardware that will eliminate the terrific stresses imposed by the conventional type of hardware as previously discussed. Furthermore, in addition to the above requirements a large thermal capacity is

necessary in a unit to enable it to resist power arcs and this demands a rather massive porcelain structure.

The design of the hardware presents a further difficulty that is solved only by a compromise between ease of assembly and security of the connection against actual failure or uncoupling. Furthermore, the hardware and shape design of the porcelain structure must be such as to resist to the greatest possible degree abrupt temperature changes.

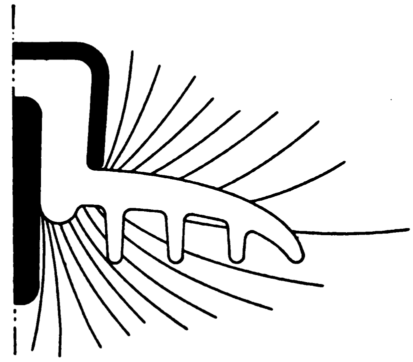

FIG. 1-a—POTENTIAL DISTRIBUTION ON THE SURFACE OF CONVENTIONAL INSULATOR, INDICATED BY THE INTERSECTION OF THE INSULATOR SURFACE WITH THE TRACES OF THE EQUIPOTENTIAL SURFACES

The voltage intervals between equipotential surfaces are equal.

DEVELOPMENT OF A RATIONALLY DESIGNED SUSPENSION INSULATOR

It is not generally appreciated by the high-tension engineers of the country that the electrical duty of the end unit is the basis of rational suspension insulator designs. Fig. 2 gives the distribution of voltage on the units of a string of suspension insulators, and it will be noticed that the conductor unit is carrying by far the greater proportion of the voltage stress. This unit is, therefore, the key to the design as, if it is so designed as to be safe, the rest of the units are obviously well within safe limits of engineering practise. The curves of Fig. 3 may be of interest, giving the percentage of the total voltage across an insulator string that is carried by the line and tower units respectively.

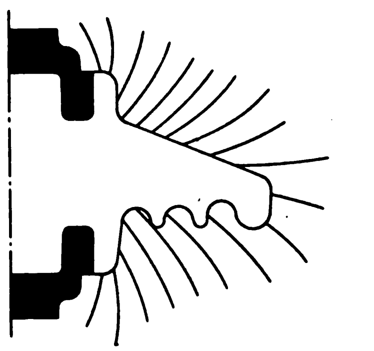

FIG. 1-b—POTENTIAL DISTRIBUTION ON THE SURFACE OF RATIONAL SUSPENSION INSULATOR, INDICATED BY THE INTERSECTION OF THE INSULATOR SURFACE WITH THE TRACES OF THE EQUIPOTENTIAL SURFACES.

The voltage intervals between equipotential surfaces are equal.

These figures bring out to a marked extent the advantage of a proper distribution of the equipotential planes as previously discussed in that such distribution produces a unit in which the corona voltage is very high. The reason for this unequal distribution of voltage has been discussed in engineering literature of recent years and will not be commented on here. In this connection, however, Fig. 4 is illuminating in the light that it sheds upon the distribution of the equipotential planes on an insulator string. This method of illustration is most graphic in showing the actual physical conditions surrounding an insulator string under operating conditions.

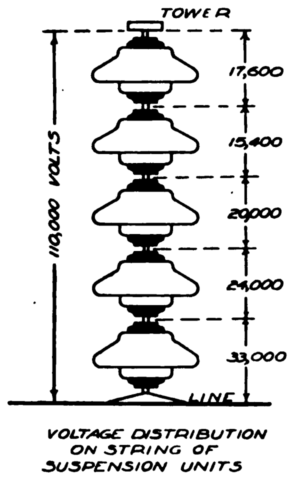

FIG. 2

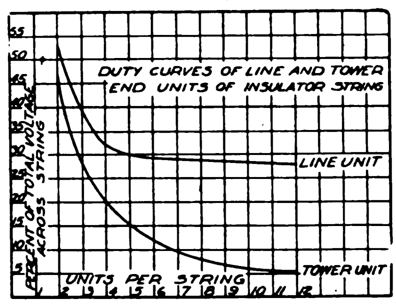

FIG. 3

Referring again to Fig. 2, it is seen that under the conditions given with a five-unit string on a 110,000-volt delta-connected line (conditions which are being successfully met at the present time by the rational design under discussion), the conductor unit is subjected to a normal-frequency voltage of 33,000 volts. The maximum high-frequency transient that has been reported by writers and investigators as likely to be met with high-tension transmission lines is around 100,000 volts. It has been shown that the effect of the normal and high-frequency voltages combined in a circuit is to produce stresses which are the arithmetical sums of the normal and high-frequency voltages. This is readily understood as according to the law of probability, the high-frequency and normal voltage peaks will coincide in time relation a certain

percentage of the time. The very high time-lag of such highly damped high-frequency transients as are encountered on transmission lines, renders possible the application of such combined voltage stresses to an insulator without flashing it over. In other words,

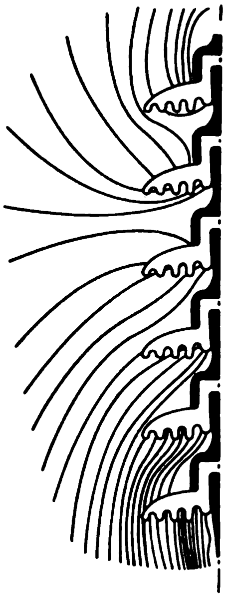

Fig. 4—Distribution of Potential Across String of Insulators

Taken from "Distribution of Potential about High Voltage Insulators—Alcutt and Skolfield, *Journal of Electricity*—June 17, 1916.

the line unit in Fig. 2 might have impressed upon it a total stress of 133,000 volts and though the flash-over voltage of the unit is 100,000 volts this unit would not flash over under these conditions due to the large time-lag just mentioned. As insulators should operate with an adequate safety factor, it is obvious that under such conditions a puncture value of around 300,000 volts at 60 cycles is necessary. In other words the puncture voltage of a rationally designed suspension unit should be in the neighborhood of three times the dry flash-over voltage at normal frequency and this is the fundamental basis of the design of rational suspension insulator units.

While leakage is a question very largely hinging upon particular climatic or other conditions a rational shaped design has been found to improve the ability of a given length of surface leakage path to limit the leakage current. Instances are known of ideal shape designs wherein the flash-over of the insulator was the same when previously cleaned, as when covered with a considerable coating of dust. This, of course, is an extreme condition but the fact remains, and has been demonstrated in the laboratory, that proper surface shape is much more efficient in this respect than surfaces wherein the divergence from the direction of the lines of force is marked. The length of the leakage path of a suspension type insulator is rather limited. The units are 10 in. (25.4 cm) or 11 in. (27.9 cm) in diameter, and if many thin petticoats are added to the unit to increase the leakage distance they are rendered much more susceptible to destruction by power arcs on account of the thin porcelain necessarily involved.

Porous porcelain is undoubtedly the cause of a great deal of insulator depreciation. One large insulator manufacturer has recently made the published statement that non-porous porcelain could not be made, stating, "a low moisture absorption is desirable, but it must not be assumed that any satisfactory porcelain can be made which will have zero absorption." This statement is absolutely challenged. One of the first objections to a rational insulator design was made by ceramic people who stated some years ago to the author that there was no doubt that such a design was desirable but that it was impossible to make a porcelain insulator of the shape, volume and thickness necessary without having it very porous. After a great deal of factory and laboratory research this problem has been solved and insulators can be made in practically any size or shape of absolutely non-porous porcelain as determined either by the psychometer or impregnation tests. This matter will be further discussed later in the paper.

It is well-known that the efficiency of an insulator string is a function of the ratio of the capacitance of the metallic interconnecting parts between the disks to ground to the capacitance of the insulator itself as a condenser and that the string efficiency is improved as this ratio decreases in numerical value. This point must be carefully considered in any rational design and hardware with a large surface between the units avoided as much as possible.

The advisability of a high impulse ratio has been admitted only quite recently by engineers in general,

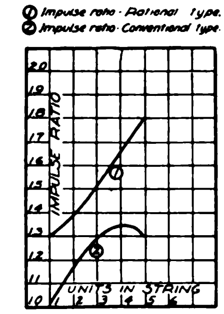

Fig. 5

and this feature is of importance because the impulse ratio is a measure of the ability of the insulator system to withstand lightning frequency flash-over. The impulse ratio of a unit and of the string built up from such units is a very important feature of insulator design, and one which has not received the attention that it should have received from most manufacturers.

The voltage at which corona appears on a unit is of great importance as a reference to Fig. 2 will show, and it is important to have this corona-forming voltage as high as possible. On a rationally designed insulator this voltage should be considerably above 30,000 volts while in many conventional type insulators at

present on the market corona appears rather decidedly at voltages from 12,000 to 16,000 volts. Fortunately the conditions necessary for the attainment of the above features of insulators influences in the right direction the value of voltage at which corona will appear on the unit. Many lines are in operation with

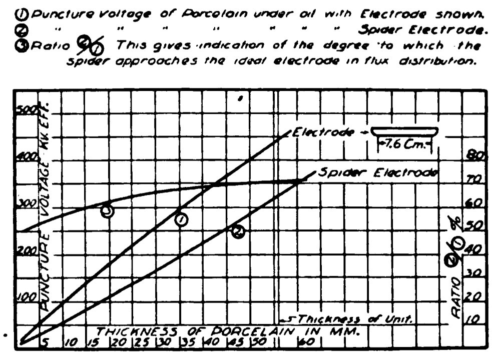

Fig. 6

conventional type units wherein additional units have been added above the actual insulation requirements of the line to insure the operation of the string without corona on the conductor unit.

The conditions discussed in general require conflicting features of design and render the design of any insulator more or less of a compromise, and the skill of the insulator designer is tested in producing the particular compromise giving the best solution under the limitations of ceramic and manufacturing possibilities. The following brief description of some of the experimental work undertaken in the research laboratories of Jeffery-Dewitt Insulator Company in the study of

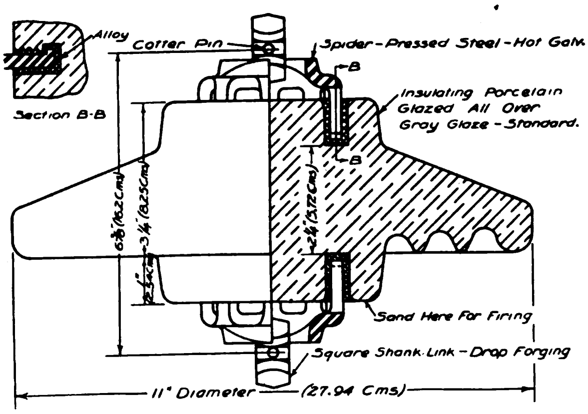

Fig. 7

the design and manufacture of suspension insulators may be of interest in showing something of the amount of work involved in such studies and something of the tendency and possibilities of future development.

Determination of the Thickness of the Dielectric Between Electrodes

As previously discussed the puncture voltage of the high-tension insulator should be approximately three times the dry flash-over voltage. Having given then an acceptable dry flash-over voltage and mechanical strength, the first problem in the design of a rational insulator is the determination of the dielectric thickness between the electrodes. The curve 1 in Fig. 6 gives the puncture voltage of one type of porcelain against thickness. This curve was obtained with the form of electrodes shown in the figure, and is the basis of the design herein discussed.

The development of the hardware to meet the requirements of symmetrical shape has been an interesting one. The first development in this design was approximately the insulator shape shown in Fig. 7, and the hardware was a solid cap at each end cemented into the porcelain. Electrically this was an excellent design, but on the application of the alternate immersion test wherein the units were immersed alternately in boiling and freezing water, it was soon found that the solid cap cemented into the porcelain was not permissible. The wide temperature variation imposed by this test damaged the porcelain rendering it mechanically and electrically unreliable. A gradual development towards flexibility resulted, after a great deal of experimental work, in the flexible spider shown in the design of Fig. 7. One of the features governing

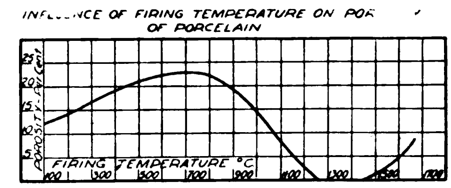

Fig. 8

the development of this spider was the requirement that the plane of dielectric stress be maintained as near as possible normal to the plane of mechanical stress a condition which this method of attachment fulfilled admirably. The legs of this spider are fastened into the porcelain by an alloy having sensibly the same coefficient of cubical expansion of porcelain. By this means the well-known detrimental effects of cement are eliminated. The flexibility of the spider legs combined with this alloy give a unit that will withstand the alternate immersion test an indefinite number of times without any detrimental effect on the insulator. Tests have been made of this character up to 100 alternate immersions followed by high-frequency flash-overs and final breaking in a tension machine. All of the tests indicate that the unit as designed is free from the detrimental effects of wide temperature variations. After the development of this spider, curve 2 of Fig. 6 was made to determine the efficiency of the spider as a flux distributor. This efficiency is given in curve 3 of the figure and shows in the thickness of the porcelain used in the unit (57 millimeters), $2\frac{1}{4}$ in., a value of 72 per cent. This value is the ratio of the puncture voltages in the same thickness with the two types of electrodes, but as the puncture volt-

age is that at which the dielectric flux concentration at its point of maximum intensity exceeds the critical value, it is also a measure of electrode efficiency as a means of obtaining a uniform flux distribution.

The difficulty of making a porcelain insulator of this thickness has deterred manufacturers from progress in this direction, and we can substantiate a manufacturer most emphatically in this difficulty. A great many thousand dollars were spent before we discovered how to manufacture porcelain in this thickness without firing strains or porosity. It may be said here that the solution involved a radical departure from the prehistoric methods of porcelain manufacture that have been followed continuously for a long time by most porcelain factories. These changes are met throughout the process from the original handling of raw materials through the final firing processes, and it is only upon the development of these special processes, utilization of special drying methods and the use of the tunnel kiln for firing control that the problem has finally been solved. Fig. 8 gives the firing temperature porosity curve for one porcelain body and illustrates the narrow range over which this body may be fired to produce non-porous porcelain. In securing this curve the porcelain test pieces were fired to various temperatures and cooled, the test being made at room temperature, that is, the abscissas on the curve represent maximum firing temperature of the sample while the ordinates are the porosity of the sample after firing and cooling. A discussion of this characteristic has been given.[1]

Tests And Investigation of The Rational Insulator as Developed

As mentioned before, the impulse ratio of a string of insulators is of very great importance and with an insulator of rational design the impulse ratio should be high. The curves in Fig. 5 are very interesting in this connection and show the excellent results secured by this rational design in impulse ratio in the individual unit and strings. The unit as designed will, therefore, for a given number of units in the string, have a very much higher flash-over to lightning disturbance than the conventional type unit with a lower impulse ratio. This, combined with the large mass of porcelain, thick petticoats and general substantial character, gives the unit a remarkable ability to withstand lightning conditions and their resultant power arcs.

The claim has been made that repeated mechanical stresses will weaken porcelain, and also that porcelain in tension is weakened electrically when under stress. In investigating this, units of the type described have been stressed to 9000 lb. (4100 kg.) in the tension machine and subjected to dry flash-over at 200,000 cycles while under stress. This test was continued until the units had been under stress for several days and at the application of high-frequency flash-over for as long periods as 100 hours there was no indication that this mechanical stressing affected in any way the dielectric quality of the insulator. This is not surprising as the plane of mechanical stress is normal to the plane of dielectric stress as before mentioned. To study the effect of repeated or continued mechanical stress, strings of insulators have been hung out in the weather with a dead load of 5000 lb. (2270 kg.) each, and periodic tests are being conducted to ascertain the condition of these insulators, and the results so far have not shown any indication that this fear is warranted. Further, repeated shocks and tension tests on porcelain samples under various conditions indicate that porcelain is not injured in any way by repeated stressing, unless the applied loads stress some part of the porcelain beyond its ultimate strength. If this is done, porcelain will fail quite naturally, as will cast iron or any other brittle material, but the results of practise and continued and careful laboratory tests indicate that the previous fear of fatigue due to continued working of the porcelain mechanically is ungrounded. These tests are being continued and some rather interesting reports will be made to the Society in the future as to the results secured from laboratory and practical tests of this nature.

Factory Tests

It is doubtful if any developed tests at the present time that can be applied to an insulator without injuring it will prophesy its operation when on the line as to depreciation and for that reason we have made a rather radical departure in some respects from ordinary factory testing.

The fuchsine method of testing for porosity[2] is used in our factory, one unglazed unit being placed in each car of 70 insulators that pass through the tunnel kiln. This unit is broken up immediately on the removal of the car from the kiln and the pieces subjected to the fuchsine test. On the slighest penetration the entire carload is rejected and scrapped. This test gives a very satisfactory control test for porosity and guards effectively against any errors in raw materials or reading of the pyrometers that might cause porosity through firing outside of the permissible range as indicated in Fig. 8. It insures the scrapping of the small number of porous units inevitable in quantity manufacture of porcelain. After the inspection of fired porcelain the hardware is assembled and each unit is subjected to a 5000-lb. (2270-kg.) mechanical load. After this load each unit receives a two-minute dry flash-over at 200, 000 cycles. The units are then again inspected and turned over to the assembly department. It is be-

[1] "High-Tension Insulator Porcelain," W. D. A. Peaslee, A. I. E. E. White Sulphur Springs, June 29, 1920. "Test of Electrical Porcelain in Factory & Laboratory", W. D. A. Peaslee, American Society for Testing Materials, Asbury Park, N. J., June 22d–25th, 1920.

2. American Society for Testing Materials, Asbury Park, N.J., June 22d–25th, 1920.

lieved that the best insurance the customer can be given as to the quality of the product he is buying is that the manufacturer started with a rationally designed product correctly proportioned and manufactured to fulfill the required conditions. A certain percentage of the finished product should then be tested to destruction to determine that the required standards of manufacture are being maintained. To this end a

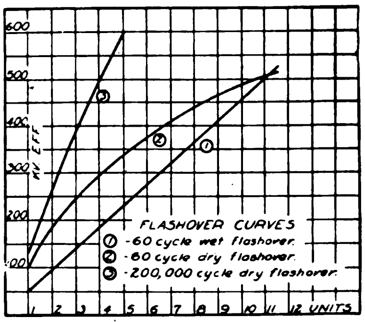

Fig. 9

certain percentage of the product delivered to the shipping department is selected at random by the research laboratory and tested to destruction. The plotting of the data secured from these tests establishes a probability curve for the product considered, the study of which has revealed some very interesting things regarding manufacturing limitations.

Furthermore, when this probability curve is once established with accuracy any test falling outside the determined limits on this curve is a danger signal and further tests are at once made. If these tests confirm the first results an immediate investigation is made to determine wherein the factory processes are not maintaining the required standards. It is believed that this method of testing is better than the imposition of very severe acceptance tests on all the units, as such tests, unless carried to destruction, tell very little regarding the future performance of the insulator.

Operating Characteristics and Selection of Units

The selection of proper insulator strings for any given transmission line involves a rather careful study of a good many conditions. Given a rationally designed insulator, the individual characteristics of which are accurately known, the selection of the number of units for a string for given conditions is a matter of the development of the proper safety factor for the right conditions, using as a basis the worst line conditions liable to arise. In this connection the curves of Fig. 9 are of considerable interest. Wet flash-over values are rather deceptive. Due to the leakage currents, the distribution of the voltage amongst the units of a string is very much improved. Furthermore, wet flash-over values are apt to be erratic unless conditions are very carefully controlled as to the purity of the water used, precipitation, size of spray, etc. In general, the selection of the proper strings involves a determination of the worst electrical conditions likely to be met on the line and the selection from characteristic curves of the insulator of a string that will give the desired safety factor under these worst conditions. The curve 3 of Fig. 9 is very interesting as a measure of protection afforded to disturbance of lightning frequency. In Fig. 10 some rather interesting data are given, that is too often ignored in the selection of insulators for a transmission line, especially when it is remembered that an increase of 45 deg. cent. (110 deg. fahr.) in temperature is equivalent to an elevation of 3000 ft. (914.4 m.) of the line. After a preliminary selection of a string has been made, a study should be made of the duty on the conductor end unit to determine whether or not from the characteristics of the insulator this unit is working within safe limits. If not, the string should be readjusted to operate this unit under proper conditions, and then the results examined on the basis of the margin of safety afforded on the failure of one unit. The readjusted values of the voltage on the different units and the resulting safety factors will give a very good idea of the advisability of further insurance against trouble by the addition of end units. This question is, of course, an economic one, and the amount of money that it is permissible to pay for such protection is a question that each engineer must decide for himself.

Future Progress

The insulator situation today is in a state of constant development and considerable progress may be expected in the near future. Certain recent investigations indicate[3] that piezo-electric effects may be of

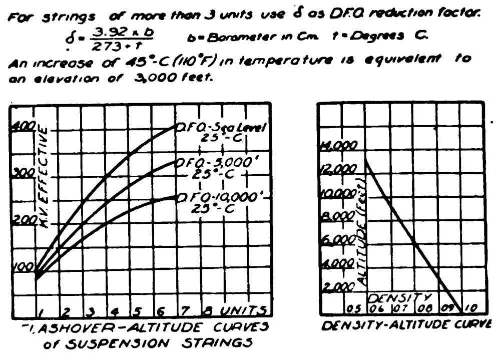

Fig. 10

considerable influence in porcelain depreciation and recent developments indicate that this situation will soon be met in a very satisfactory manner. Also some rather interesting work is being done at present on the solubility of porcelain in water under the conditions existing in the capillary passages connecting the voids of porous porcelain. Investigations are under way using pressures around 10,000 lb. per sq. in. with very

3. W. D. A. Peaslee, "High-Tension Insulator Porcelain," A. I. E. E. White Sulphur Springs, June 29, 1920.

high and very low temperatures to accelerate this action and, by means of the microscope, determine from samples of porous porcelain that have depreciated in the field compared with the porcelain subjected to accelerated tests in this manner, to what extent this solubility may be responsible for increasing porosity. The problem of very high-voltage transmission systems is being studied and some new types of insulators made up of rather special porcelain bodies are being developed that will meet this situation without difficulty and by the time there is money available to build any of the large projected extremely high-voltage lines, insulator manufacturers will be ready to meet the problem.

Carbon and Commutator Wear[1]

BY R. E. HELLMUND

Engineering Dept., Westinghouse Electric & Mfg. Co.

WITH most theories on commutation the sparking voltage between commutator segments or the average voltage across the brush is used as the principal criterion for the commutation. More recently the idea has been advanced that the problem of commutation is very much the same in d-c. and a-c. machines as long as in both types of machines the sparking voltage is properly taken into account. It has also been shown by extensive data collected under practical operation that certain sparking voltages will have very similar effect in both a-c. and d-c. machines if other conditions are kept alike.[2] This should not be construed, however, to mean that the sparking voltage is the only important factor which enters into the commutating problem, especially into the wear of the carbons and the commutator. In other words, while it is true that the sparking voltages are of the same brand no matter whether they are induced in an a-c. or d-c. machine, the same sparking voltage may give widely different results under different conditions in either type of machine. The fact that very often the comparative data obtained with the same sparking voltage give rather consistent results for the carbon wear with different types of machinery is simply due to the fact that a good many factors, as for instance, current density, temperatures, commutator speeds, etc., are similar in a great many practical machines regardless as to whether they are a-c., d-c., or whether they are for industrial or traction purposes. Nevertheless it seems to the writer that the importance of these various factors upon the commutating problem should not be overlooked and that a detailed knowledge of the various factors as affecting brush wear is of utmost importance. If it is considered how important the brush and commutator wear is in connection with all kinds of commutating machinery it seems surprising how little investigation has been made along this line. While there are quite a number of tests available giving brush friction and contact resistance, practically nothing is known as to how sparking voltages, current densities, peripheral speeds, etc., affect the brush and commutator wear. It might, therefore, be in place to give here a few tests along this line with which the writer happens to be familiar.

One test which the writer has in mind was made with rather soft graphite brushes on slip rings for the purpose of investigating the effect of sparking as often caused by mechanical vibration. The vibrations were obtained by connecting the carbons to a little mechanical device vibrated by means of an alternating current magnet. It was thus possible to produce arcs as they are at times experienced on slip rings under severe mechanical vibrations. It was found that while with very low densities in the carbon quite appreciable arcing was produced, no measurable carbon wear was found over an extended period of test. On the other hand, it was found that with very large current density but without arcing it was also impossible to measure any carbon wear. While again, when arcing was combined with an appreciable current density the carbon wear was quite rapid. This simply brings out the fact that with machines having some arcing on the brushes, the current density has an appreciable influence upon the practical results obtained. It was also interesting in connection with this test that the arcing with low densities, giving practically no wear, looked nearly as bad as the arcing with high current densities, which shows that visible commutation does not always give a measure of the wear of the carbons and the commutator.

Some other interesting facts were brought out by a series of very careful tests carried on at the writer's suggestion by Mr. H. H. Wentworth. In these tests an alternating-current railway motor was run with the brushes on the commutator but without any load current in the armature, while at the same time the fields were excited by alternating currents. In this manner it was possible to determine exactly the sparking voltages in the armature coils by simply measuring the field voltages. In so far as the test was intended for

1. This material was given in a discussion of the paper by Mr. G. B. Lamme on A-C. Commutator Motors, presented before the Schenectady Section of the A. I. E. E., April 2, 1920, see A. I. E. E. JOURNAL, March 1920. Since the writer has been repeatedly requested to publish the material given there, it has been written here in the form of a short article.)

2. B. G. Lamme loc. cit.

getting information on railway work, the excitation of the fields, and therefore the sparking voltage, was arranged to be on only half of the time in order to get the effect of coasting without sparking voltage. The field excitation was on for 30 seconds and off for 30 seconds. Furthermore, the motor was reversed in its direction of rotation every hour. Fig. 1 shows the carbon wear per 1000 miles of commutator travel as dependent upon the sparking voltage between segments. All tests were made with uniform carbon pressure and a commutator speed of about 3000 ft. per

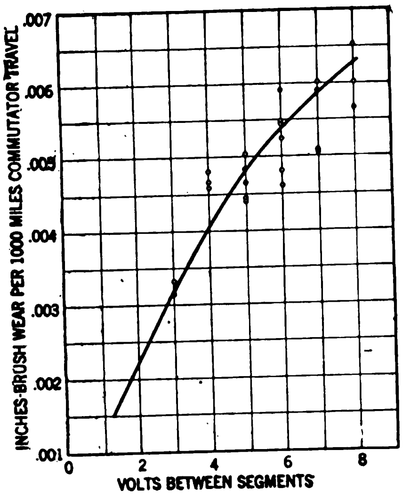

FIG. 1

min. Since the carbon covered about 1.8 segments the average voltage across the carbon is about 1.8 times the values given in the curve. It is at once surprising how small the carbon wear is as found from this test in spite of the high sparking voltages, which were as high as 8 volts between segments and 14.3 volts across the brush. This wear was only about one-fifth to one-tenth of what is obtained with the motor in actual operation with high current densities in the carbon but appreciably lower sparking voltages. This again bears out the fact that the current density has an appreciable influence on the current wear. It is, however, not altogether safe to conclude from these tests that the load current densities have directly as much influence as might be supposed from casual inspection of the tests. It was noticed on an inspection of the carbons on this test that they showed a very bright surface near both edges over small distances b and c, Fig. 2, while the center portion marked d showed plenty of evidence of arcing. This condition was obtained on account of the tilting of the carbon in the holder, although the clearance was kept down to a practical minimum the tilting was found to be unavoidable. The natural consequence is that the carbon instead of actually short-circuiting 14.3 volts covered only a distance c of the commutator and this short circuited a very much smaller average voltage. The relatively small short-circuit currents formed over the distance c, had plenty of time to be interrupted over the distance d, burning it slightly, but apparently never reached the portion b, as otherwise they would have taken off the polish from this part of the surface during the hour run in the same direction. In other words, the small carbon wear in the tests cited is largely due to the fact that the actual short-circuited voltage was not nearly as high as indicated by the curves. While running light, as in these tests, the wear of the portion c would be kept very small simply because the short-circuited currents and the local densities were small. It is probable, however, that as soon as the load current is sent through the brush the densities in the small portion c will be so excessive that the surface would quickly disintegrate and cause a rapid wear, thereby bringing at the same time a larger portion of the brush into contact with the commutator which indirectly increases the short-circuited volts and the short-circuited currents; thus the presence of the load current not only raises the density directly but indirectly raises the sparking voltages across the effective brush contact and consequently the densities caused by the short-circuited currents. In other words, we have a cumulative effect, causing the very much increased brush wear.

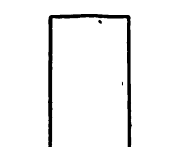

FIG. 2

Another interesting fact developed in connection with this test, namely, that the carbon wear without any sparking voltage was considerably higher than the wear with moderate sparking voltages. For this reason the curve in Fig. 1 is not carried to the zero point. This fact is first somewhat surprising but may be explained by the fact that the friction of carbons usually is lower with currents than without. It seems that the flow of any current affects the carbon so that the small graphite particles are loosened, and serve as lubricant, thus reducing the friction, and therefore, the carbon wear. It was further surprising to find that with the tests referred to, which were carried on with no sparking voltage for half the wear obtained with no sparking voltage at all. It was later found, however, that while the friction went down as soon as the sparking voltage was put on, it would take some time before the friction would increase after the sparking voltage was interrupted. This is undoubtedly due to the fact that the graphite particles caused by the flow of the short-circuited currents continue to adhere to the commutator for some time after the effect of the current had stopped. This brings out the interesting fact that while a short coasting period in railway motors may have a beneficial influence all around it may be found that a long coasting period is not very advantageous with respect to carbon wear. This, of course, does not mean that a long coast is not beneficial insofar as it cleans the commutator. On the contrary the higher friction during coasting, causing increased wear

for both carbons and commutator is often essential in giving successful operation. This is especially true with non-undercut commutators, but also to some extent with undercut commutators to which these tests apply.

Fig. 3 shows some further interesting curves obtained with the same motor. They show the dependency of the brush wear upon the commutator speed for various sparking voltages. It will be seen that the wear for low speeds is comparatively higher, that it subsequently decreases for higher speeds, but then increases again for still higher speeds. The high wear at low speeds is easily explained because with such low

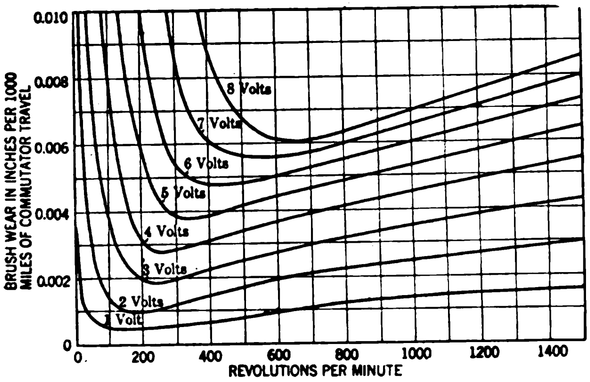

FIG. 3

speeds the carbons are in intimate contact with the commutator and each coil is short circuited long enough to permit the short-circuited currents to fully establish themselves, and furthermore, in opening the short circuits a long arc can be drawn out having plenty of time to bring about considerable burning effect. It is also natural with increasing speed that the inductive effect of each armature coil does not permit the short-circuited currents to build up to the full value and the time for the arc to burn off particles is materially reduced. It is somewhat more difficult, however, to explain why the wear again increases with the higher speeds. It may be that the vibrations set up with the higher speeds cause the carbon to jump up and down on the commutator thereby causing an arc under all portions of the carbon, thus causing greater wear. This supposition is somewhat supported by the fact that in the tests made there was an appreciable carbon breakage with the higher test speeds. It seemed that around 1400 rev. per min. a natural period was approached which caused sufficient vibration to bring about carbon breakage. This incidentally explains the carbon breakage experienced with some railway motors in operation in a good many cases where previously gear vibrations or other mechanical shocks experienced in railway work were supposed to be the cause of the carbon breakage.

An attempt was made to explain the higher carbon wear by higher losses in the contact surface. For this reason the short-circuit losses were determined and found as shown in Fig. 4. It is at once seen that the large wear at low speeds coincides well with high losses at the same speeds. On the other hand the loss curves show no increase for high speed corresponding to the rise of carbon wear for these speeds.

Possibly the higher carbon wear at the higher speeds might be explained by the theory that the lubricating graphite particles are thrown off the commutator by the centrifugal forces to a larger extent. This would, of course, result in increased friction and consequently in increased wear.

Another possible cause for the higher carbon wear at the higher speeds might be the fact that the high speed of interrupting the current causes sufficient self inductive voltage to maintain the arc longer, thus causing additional carbon wear. This leads to a point which has been given too little attention in all commutating theories. In machines having low sparking voltages and therefore no arcing at all, this point is, of course, of little importance, but in any case where appreciable short-circuited currents can form, the self induction of the armature coil will, of course, materially increase any sparking voltage at the moment the short-circuited current is quickly interrupted while one of the segments leaves the carbon. The fact that this self-inductive kick has an appreciable influence on the commutator wear was brought out very noticeably in some alternating-current motors under extreme operating conditions. It was found that certain commutator bars burned more than others. The reason for

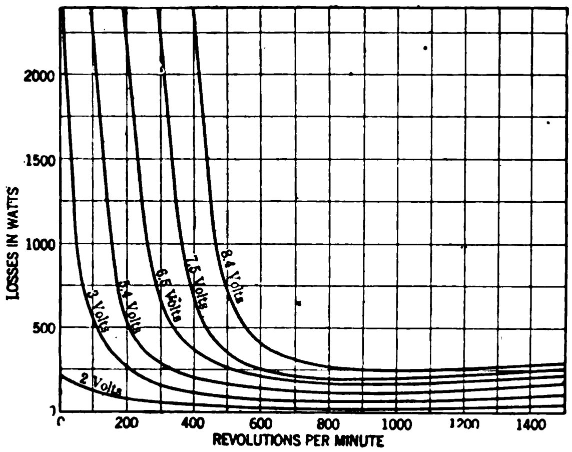

FIG. 4

this can be very readily explained in combination with Figs. 5 and 6. Let us assume, for instance, that the coil 1 is short-circuited and segment *a* is about to leave the carbon while at the same time coil 2 is being short-circuited on account of the segment *c* coming under the carbon. This means that the short-circuit current in coil 1 is decreasing while that in coil 2 is increasing, consequently the sum of the two-short circuited currents remains about the same and the flux surrounding the coils, as indicated by the dotted line does not need to change while the short-circuit currents

are transferred from coil 1 to coil 2. This in turn means that there will be no inductive kick when the segment 2 leaves the carbon, and therefore, there is no burning on segment *a*. The same holds true when the short circuit is transferred from coil 2 to 3 and from 3 to 4, meaning that there will be no burning on segments *b* or *c* either. The conditions change, however, materially when the short-circuited current of coil 4 is interrupted. In this case the flux around this slot disappears and a new flux forms around the next slot. Therefore, we will have an appreciable inductive kick when the segment *d* leaves the carbon, and this is the reason why this segment burns appreciably. A marked improvement was obtained in the case under consideration by adopting a coil with split throw, as shown in Fig. 7, with which only one coil side loses its flux at a time. Therefore, the inductive kick is cut to half its former value. In fact it can be shown that with such a winding and the motor rotating in both directions of rotation the burning is uniformly distributes over all the bars, thereby giving uniform wear of the commutator and avoiding the cumulative burning of the segements which will always be experienced when the wear is not uniform.

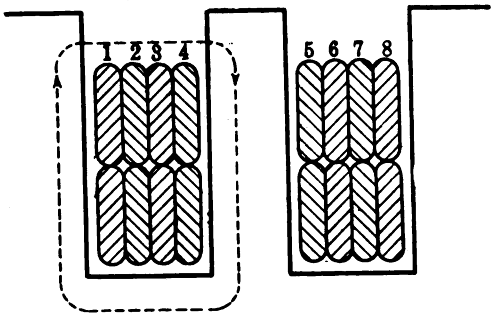

Fig. 5

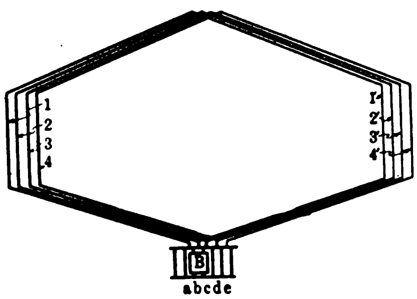

Fig. 6

While as previously brought out, a certain sparking voltage will have the same effect under otherwise equal conditions no matter whether it appears in an a-c. or d-c. machine, attention might here be called to one difference in conditions existing between a-c. and d-c. machines. In a d-c. machine the current density as well as the sparking voltage is more or less uniform for a given load current and both exist at the same time.

In other words, the short-circuit currents caused by the sparking voltage are uniformly superimposed upon the load current densities in the carbon. In a-c. machines this is not true with regard to all of the sparking voltages. While there is also one sparking voltage which is caused by the rotation of the conductors in the fields set up by the armature magnetic motive force which is in phase with the load currents, there are other sparking voltages in a-c. machines which are out of phase with the load current. The fluctuations of the main field in the single-phase series machine for instance, induces a sparking voltage which is 90 deg. out of phase with the load current. Therefore, the short-circuit currents set up by this voltage are out of phase with the load current. It is quite possible that with the two current densities being out of phase the commutator and carbon wear will be found different than that obtained when the load current density and the short-circuit current density are in phase with each other. In fact practical experience indicates that any sparking voltage being out of phase with the load current density causes smaller carbon wear than a sparking voltage which is in phase with the load current.

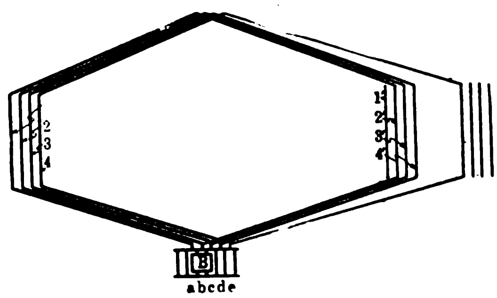

Fig. 7

The above tests and facts are merely cited in order to stimulate some interest in this problem as a whole and in order to indicate how the brush and commutator wear is appreciably influenced by various factors. The tests given here are too incomplete to allow any safe conclusions or to fully support some of the ideas advanced in the discussion. It would, therefore, seem very desirable that similar investigations determining the influence of current density, temperature, speed, etc., be carried on in the future, and it is believed that by acquiring, in this manner, full knowledge of the various phenomena it will be possible to extend considerably the practical working limits of all commutating machinery.

A Direct Recording Method of Measuring Magnetic Flux Distribution

BY F. S. DELLENBAUGH, JR.

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General Problem

IN undertaking an investigation in some of the more elusive refinements of dynamo-electric machinery design it became necessary to measure and analyze such a multitude of curves of flux distribution, that the labor and time required by existing methods practically prohibited the investigation. After some experimentation the method described was developed, which has the advantages of speed, accuracy and minimum effort in producing results.

This apparatus represents merely one detail of the means toward an end, and is rough in construction, being assembled from materials at hand, but the results are so satisfactory that it was thought advisable to describe the method in order that others might avail themselves of its simplicity.

Principle of Apparatus

The most common method of measuring flux distribution involves a search coil and ballistic galvanometer. Those who have worked with this method will readily appreciate the time involved in making a detailed survey of a magnetic field of any extent. Other methods such as the Grassot fluxmeter, change in resistance of bismuth wire, integrating volt-second meter etc. were investigated, but for one reason or another did not lend themselves aptly to the particular problem.

A revolving search coil fitted with a collecting device and operating at a high and constant speed was then thought of. The only objection seemed to be possibility of contact trouble at the brushes. The principles involved are the same as in any rotating generating machinery, the particular form of the parts being extreme. There appears to be no record of its having been previously tried, in spite of its simplicity of idea and somewhat obvious application.

In brief the apparatus consists of a search coil of very small diameter, and length approximately equal to the surface across which the flux distribution is to be examined, wound with a closed-coil winding and fitted with a commutator. The coil is rotated by a small storage battery motor, fitted with a governor to control the speed, and a magneto to indicate the speed. The voltage generated in the coil will then be proportional to the flux density of the field in which it rotates, other factors being constructed or maintained constant.

This voltage may then be read on an indicating meter or better, projected upon a photographic recording device by a reflecting instrument. The commutator was chosen rather than slip rings, first, because the component density in a definite plane may thus be determined, and second, because of the greater sensitivity and simpler technique obtained with direct-current instruments.

Details of Construction

Fig. 1 shows a drawing of the search coil. The "armature core" is constructed of bakelite to avoid eddy currents, 0.22 inches in diameter, about four in. long, and has four slots 0.05 inch wide by 0.07 inch deep. On each end a brass cup is attached, the small one on the left being merely a bearing to steady the coil, and the long extension on the right carrying the commutator and extension for attachment to the driving motor.

A four-part commutator is used, as a compromise between too greatly fluctuating voltage with two parts,

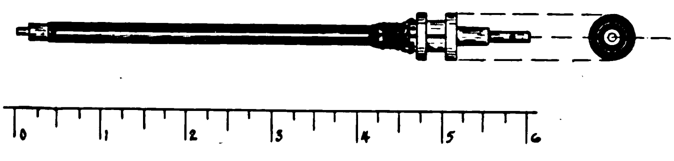

Fig. 1—Search Coil. Bakelite Core, Four Slots, Four Bar Commutator.

and two great construction difficulties with a greater number of parts. The bars are made of gold, mounted upon a hard rubber sleeve and held in place by hard rubber "shrink rings" reinforced with brass. The dimensions of the commutator are 0.25 in. diameter by 0.15 in. face.

The winding consists of five turns per coil of No. 38 d. s. c. copper wire, connected in the usual closed coil manner, with the bars placed so that a line drawn through the commutating points is in the same plane as the magnetic field generating the voltage, and the brushes therefore at right angles to the field, tangential type being used. This allows the coil to be approached close to the magnetic surface being explored. The brushes themselves consist of laminated strips of thin phosphor bronze tipped with silver, and are mounted so that they may be rotated around the commutator through 180 deg.

The coil is driven by a small motor, in this case a six-volt "Klaxon" horn motor being used. It is considerably larger than necessary but it was the smallest available. Fig. 2 shows the complete assembly of coil

motor, and governor. The magneto was not attached at the time the photograph was made. The second rod projecting from the bottom of the motor is a steady-rest for the end of the coil, as otherwise it will not run

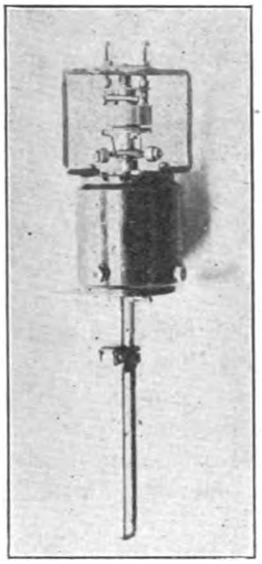

FIG. 2—SEARCH COIL AND DRIVING MOTOR SHOWING COIL AND STEADY REST, WITH GOVERNOR ON TOP OF MOTOR

entirely true due to slight unbalance and slight warp in the bakelite.

SPEED CONTROL

As the speed control is very important, Fig. 3 shows a drawing of the governor, which is a combined centri-

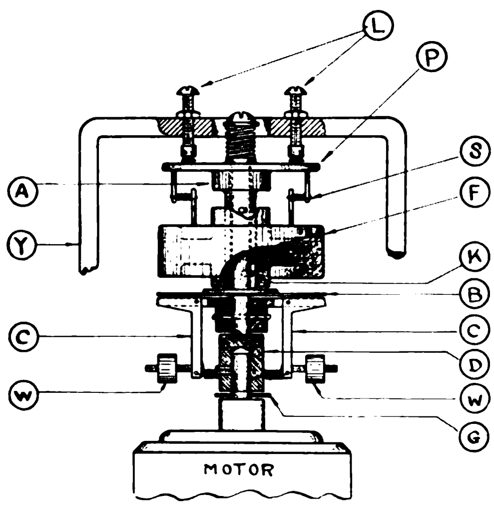

FIG. 3—GOVERNOR. COMBINED INERTIA-CENTRIFUGAL TYPE FOR CONTROLLING SPEED

fugal and inertia type. The collar *D* carries a shaft which runs up through the whole device. It also has fixed to it a plate which carries the three centrifugal weights *W* at the ends of the bell-crank arms *C*. These weights are threaded upon their carrying pins in order to balance for running speed. When these weights fly out they push up on the plate *B* which lifts both the flywheel *F* and the friction plate *P*, and forces the latter against the leather friction rubbers *L*. So far it is similar in action to the well-known phonograph governor. It was found, however, that this type alone allowed small instantaneous fluctations or jumps in speed, which would occur before the centrifugal weights

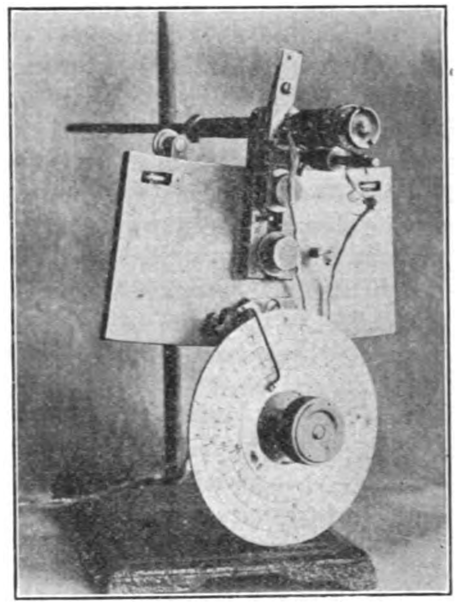

FIG. 4—CARRIAGE FOR SEARCH COIL. IN THIS CASE WITH TYPE OF COIL USED WITH BALLISTIC GALVANOMETER. MOTOR DRIVEN COIL REPLACES PART MOUNTED ON SLOTTED BRACKET

had time to act, and introduced breaks and inequalities in the recorded results. Therefore the flywheel *F* was added. This runs loose upon the sleeve *K*, which sleeve carries the friction plate, and is keyed to the shaft so that it can rise and fall, but must turn with the

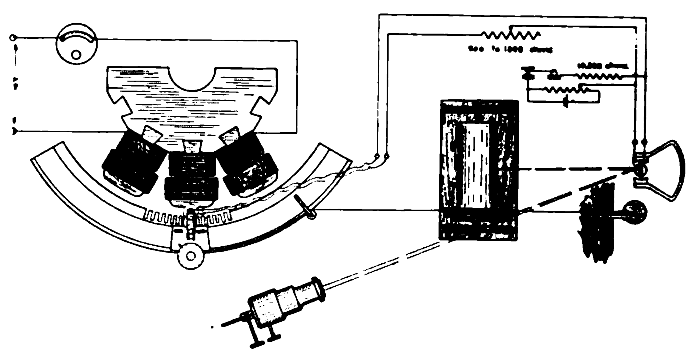

FIG. 5—GENERAL ARRANGEMENT OF TEST APPARATUS. SHOWING TEST COIL CARRIAGE, SECTION OF ALTERNATOR PUNCHINGS BEING EXAMINED, REVOLVING DRUM, REFLECTING METER, AND ARC LIGHT

motor. Therefore the flywheel running loose upon this sleeve will tend to run ahead or behind as the motor is retarded or accelerated. The upper end of the flywheel has two sloping notches in which rest pins attached to the friction plate sleeve. Thus rotation of the flywheel with respect to the sleeve tends to raise the friction plate when in one direction, and allows it to fall when in the other direction. Thus very small fluctuations in speed are immediately corrected by the

flwheel shifting its position with respect to the sleeve and increasing or decreasing the pressure upon the friction rubbers independently of the centrifugal weights. Very light springs S locate the normal position of the flywheel so that the pressure upon the friction plate is always carried through the pins and sloping notches.

Speed. Measurement

A small magneto, not shown, is attached to the top of the whole assembly and is calibrated to read speed

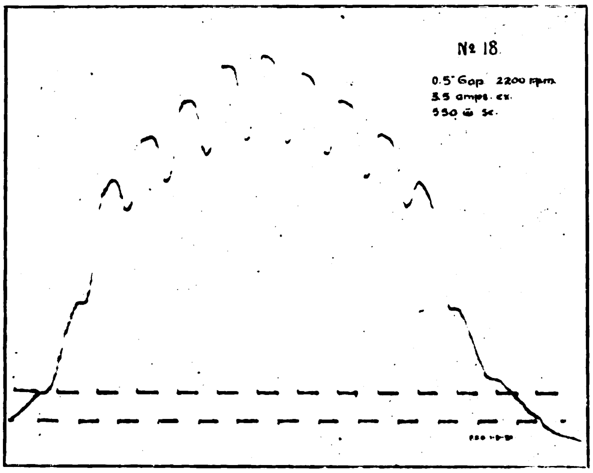

Fig. 6—Flux Distribution in Air Gap. 0.5-in. Air-Gap, Coil Moved Along Core Face. Position of Teeth Shown at Bottom

with an indicating millivoltmeter. This consists of a shuttle type armature 0.35-in. diameter wound with 200 turns No. 40 d. s. c. wire connected to a two-part commutator, and excited by a permanent magnet from a small voltmeter, the magnet being circular and about 2.5 in. in diameter. The voltage generated is about 100 millivolts at 2000 rev. per min. and as the peripheral speed of the commutator is only 80 feet per minute, no trouble with commutation has been found.

Recording Device

Some difficulty was experienced in obtaining a reflecting instrument that would follow quickly and truly the variation in voltage generated in the search coil. Galvanometers were too sluggish when critically damped, and would overshoot when not damped. The ordinary standard millivoltmeter has too low resistance and required enough current to cause commutating troubles, as well as large errors due to drop in coil. Vibration galvanometers or oscillograph elements either required too much current, or would pick up the frequency of commutation and vibrate continuously. Therefore a Weston ammeter was rewound with No. 40 d. s. c. wire, enough being wound on the moving coil to give 144.6 ohms resistance. The needle was bent back over the suspension, and a mirror fastened upon it centrally over bearings. This was found to give excellent results. It is very nearly critically damped and follows any change in voltage with great rapidity. Its sensitivity is quite high, giving a deflection of one cm. at one meter with 2.14 millivolts across its terminals, or 0.0148 milliamperes through the coil. This is about ten times the sensitivity of the standard millivoltmeter.

Arrangements of Apparatus

For the immediate problem in hand a section of a 12-pole alternator is set up horizontally on a table, the field coils excited, and the core being bare. A carriage running on a wooden track concentric with the core face carries the search coil assembly. Fig. 5 shows the arrangement schematically. A curved rack on the wooden track meshes with a gear on the carriage, and the gear carries a micrometer head graduated so that the position of the coil can be read to 0.05 tooth pitch. The search coil is mounted upon a slotted bracket so that it can be moved through any given plane in the air gap. Fig. 4 shows the carriage with an old type of search coil in place, which was rotated by a spring through 180 deg. when released by a trigger to obtain readings with a ballistic galvanometer. This is replaced directly by the present device, the remainder of the carriage remaining the same.

The reflecting meter is mounted upon the extreme right, and light from a small arc lamp, shown in lower center, is reflected upon a large drum. A small wire connects the drum pulley to the search coil carriage, and thus rotation of the drum is a function of the search coil position. The wire is arranged by means of pulleys so that it follows the arc of the wooden track, and after going once around the drum pulley, is attached to a counterweight.

The reflecting meter is connected to the search coil and also to a second circuit in parallel operated by a key. This is used to locate definite points on the curve by giving a small deflection when the contact is closed.

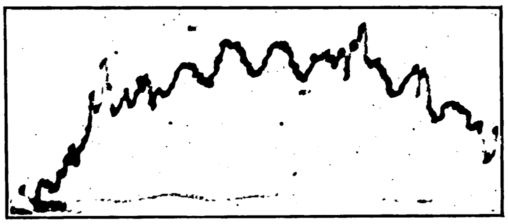

Fig. 7—Curve Obtained Without Governor and Commutator Improvements. Same Conditions as Fig. 6

Results Obtained

Fig. 6 shows the curve of flux distribution in the air gap along the armature core face. The positions of the teeth are shown at the bottom, being put in by means of the hand-operated key after the other curve had been made. The lines representing the bottoms of the slots are also the zero line of the curve. The depth of the slots is not to scale, but the width of the teeth and slots is accurate to 0.05 tooth pitch. The small wiggles in the curve at some places appear to be due to irregularities in the surface of the wooden track, as they are duplicated in the same spot with all curves.

Fig. 7 shows one of the first curves made before the motor was governed, and when there was also some

vibration in the brushes. It is included here for contrast and to indicate how successfully it is possible to eliminate the various sources of error.

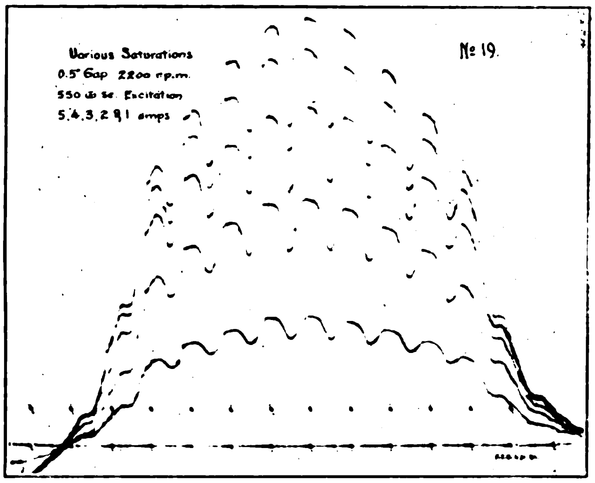

Fig. 8—Flux Distribution for Various Saturations. Points Above Zero Line Indicate Centers of Teeth

Fig. 8 shows a series of curves made at various saturations with the search coil close to armature core face. The saturation did not reach a high enough value to obtain noticeable change in the "tooth tufting". The maximum value of density was in the neighborhood of

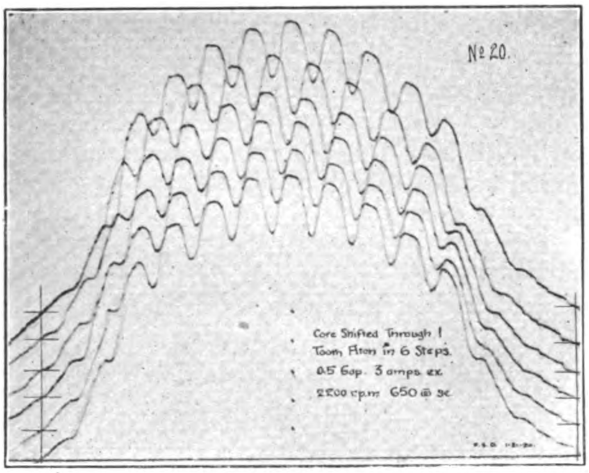

Fig. 9—Flux Distribution for Various Relations of Teeth to Pole. Core Moved a Little Around Pole for Each Curve. Total Movement from First to Last Curve One Tooth Pitch. Zero Line of Each Curve Displaced from Preceding One to Avoid Confusion

8000 gausses in the air gap. The zero line was put in by a second rotation of the drum with the search coil disconnected, and the dots above it represent the centers of the teeth, put in by means of the second circuit and key.

Fig. 9 shows the distribution of flux for the same saturation, but with the core shifted slightly with respect to the pole for each curve. The total shift between the top and bottom curves was just one tooth pitch, but the intermediate positions were not even fractions of the tooth pitch, although it was attempted to get them close to 1/6 pitch each, in order to obtain a smooth series. The zero point of each curve was displaced in order to avoid over-lapping and too much confusion.

The air gap in all the above curves was normal, 0.5 inch. In Fig. 10 the gap was increased to 1⅛ inches in order to exaggerate the results. Curves were then made for various positions of search coil from close to core face to close to pole face. The zero lines were displaced as before to avoid overlapping. The unbalance noticeable in the curve along pole face is due to the fact that only three poles are present, the distribution being investigated under the middle one, and slight differences in reluctance of either side pole unbalances the flux.

These curves are all made directly on photographic paper, size eight by ten inches, and have a base of

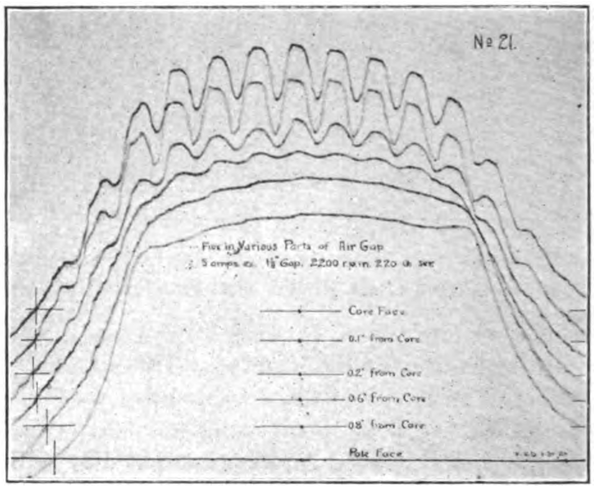

Fig. 10—Flux Distribution at Various Points in Air Gap Between Core Face and Pole Face. Air Gap Increased to 1 1/8 in. Zero Line of Each Curve Displaced from Preceding One to Avoid Confusion

about nine inches by maximum ordinate of about seven inches. This is convenient size, both for further treatment, and because they will file easily in standard letter file. The convenience of using paper instead of films eliminates a good deal of bother owing to a dark-room being unnecessary. All curves shown were made in an ordinary room in day time with the shades pulled down and black muslin hung up where the light was too intense. An old carbon incandescent lamp was used for local illumination to determine the setting etc. and is perfectly safe with most "gaslight" papers. The search coil is moved through the gap at a speed of about two feet per minute, and so gives ample time for exposure. It can be operated at about twice this speed without distorting the curves, and can be operated slower if longer exposure is necessary. Any "gaslight" paper may be used, these particular curves being made on AZO Hard-X developed in letol-Hydroquinone developer deficient in sodium carbonate, and well loaded with potassium bromide and potassium iodide

to give as much contrast as possible and cut down the small amount of fog present.

Accuracy

Enough work has not as yet been done with this apparatus to determine definitely the accuracy to be expected, but it seems to be quite high. The speed control holds to within 0.1 per cent for short periods, and within 1 to 2 per cent for periods of an hour or so. The speed can be read by the magneto to within 0.5 per cent easily, and the larger variation corrected before making a curve.

The contact resistance at the brushes of the search coil varies somewhat, but is very small percentage of the total resistance in circuit. The resistance of the search coil and brushes measured under conditions of speed varying from standstill to 3600 rev. per min. and current varying from normal to several hundred times normal, gave extremes of 1.23 ohms and 1.57 ohms. In actual use from 500 to 1000 ohms is used in series with the coil and reflecting meter, and 144.6 ohms in the meter circuit, makes a total minimum of about 646 ohms. The total variation in resistance of the coil is only 0.34 or 0.0525 per cent and so entirely negligible.

Under normal conditions the distance of drum to mirror is 24 in. and maximum ordinate 7 in., which requires a current in the meter coil of 0.434 milliampere. This gives an error of only 0.46 per cent if we neglect the resistance of coil and leads entirely. Its distortional effect upon the field being measured appears to be entirely negligible.

The accuracy of converting coil voltage to flux density depends upon the accuracy with which we can determine the area of the cross-section of the windings on the coil. By the ordinary theory of generating machines we find that the flux density is determined by the formula:

$$B = \frac{E \times 60 \times 10^8}{2.548 \times \pi \times \text{rev. per min.} \times n \times A}$$ for four-coil winding

where: B = Flux density in which coil operates.
E = Voltage coil generates.
n = Turns per coil in winding of search coil = 5.
A = Area of one coil of winding on search coil.

Thus the value of A is the only one indeterminate. In the present case this is about 0.06 square inch. It has also been found that the best operating speed is from 1800 to 2500 rev. per min. Below these limits uncontrolled friction is too great a part of motor load and the speed varies, and for higher values it does not run sufficiently well in balance to avoid vibration and difficulty with commutation. All the curves shown were made at a speed of 2200 rev. per min. It will be seen that the generated voltage has a magnitude of from 200 to 500 millivolts for normal air gap densities. Probably the most accurate way of determining the relation between voltage and flux density would be by calibration against a definite smooth magnetic field set up by a special magnet, and measured by ballistic galvanometer methods. This is a little roundabout, but by many trials and different conditions should lead to an accuracy of 1 per cent.

Therefore in general we should expect a combined accuracy of well within 2 per cent, and possibly within 1 per cent. It is believed that this compares favorably with other methods of obtaining similar results.

Speed of Obtaining Results

The time necessary to obtain one curve such as Fig. 6 by means of a ballistic galvanometer and point by point plotting method was at least an hour and a half and usually two hours. The time to make Fig. 6 was five minutes including all adjustments and developments.

Fig. 8 took ten minutes, for although having five curves, the majority of the time is required for setting up the various parts and making preliminary adjustments.

Fig. 9 took twenty minutes, since the adjustments between curves were more laborious.

A total of 31 curves was made easily in three hours, which works out at about six minutes per curve for an average, including adjustments of all kinds, and the usual details connected with any tests of this sort.

In an investigation such as the one under consideration where at least a thousand of such curves must be made, the time for making them by ballistic galvanometer method would be something of the order of two years, on the part time basis covering this investigation and is reduced to approximately five weeks by the above described device.

Further Developments

It is probable that a silver commutator and silver brushes similar to those used on d-c. integrating wattmeters would give more satisfactory results than the combination of gold and silver. The latter needs occasional lubrication with a trace of graphite. The motor could be reduced considerably in size and probably some form of synchronism motor would eliminate speed troubles. It is hoped shortly to reconstruct the device, so that the search coil will be still smaller in diameter, fully enclosed, so that it may be moved by hand against surfaces investigated and not require a track and carriage, and the driving mechanism all enclosed in a handle. In this form the whole thing will be light and portable. A small governed motor-generator set will probably provide a desirable form of power, machines the size of 8-in. fan motors probably being large enough, and operated from a six-volt storage battery. The recording device can be made much less bulky and arranged to fold like a camera, so that it becomes easily protable. A tungsten lamp would probably give enough light for drawing the curves, and the apparatus can be loaded in a dark corner or under a blanket and does not require a dark-room and safe lights. When these improvements have been made it will be possible to carry it to a machine anywhere and investigate flux distribution in detail with convenience and dispatch.

A Note on the Design of Insulating Bushings

BY F. M. DENTON

Northampton Polytechnic Institute, Clerkenwell, London.

THE break-down of an insulator usually sets in at the spot where the density of the electrostatic flux due to the conductor it is intended to insulate, is a maximum; for, as is well-known, this density is a measure of the volts per centimeter acting at that point upon the insulating medium. Observation of the discharges from an electrostatic machine shows that the atmosphere around a highly charged conductor breaks down most readily at points and sharp corners, while both theory and experiment show the advantage, if corona is to be avoided, of using, for a high-voltage transmission line, conductors of large diameter.

When, therefore, an insulating bushing has to be designed, for bringing the leads of a transformer or of an oil switch or lighting arrester through the metal case containing the apparatus, it is common practise to pass the actual conductor—a wire of small diameter—through a brass tube one or more inches in diameter forming the core of the insulating bushing. The electrostatic flux density at the surface of this tube—to which the high-voltage conductor is electrically connected—will be less than the density which would exist at the surface of the thin conductor if this were passed unsheathed through the bushing.

So far as the writer is aware it is customary to use as sheath a metal tube of as large a diameter, $2\,r$, as space will conveniently permit, and then, assuming a figure for the volts per centimeter $(d\,v/d\,r)$ to which the insulating substance may safely be subjected, to find the minimum allowable value for the external diameter $2\,R$ of the bushing from the equation.

$$\left(\frac{d\,v}{d\,r}\right) = \frac{V}{\{r \log_e (R/r)\}} \qquad (1)$$

in which V is the maximum instantaneous value of the test voltage that will be applied to the apparatus. This equation, though applicable, strictly, only to long co-axial cylinders, is found to give satisfactory results for transformer bushings and the like provided the edges of the metal sleeve through which the bushing passes are well rounded off.

The object of this note is to point out that the method of design which starts from an arbitrarily assumed value either of r or R is apt to lead to a larger and more costly bushing than the working conditions actually call for, and to show how, by the application of two simple rules, the most economical design can readily be worked out.

In conclusion a few published designs will be analyzed and compared with the most economical designs to which the rules given would have led.

It must, of course, be understood that, strictly, the rules are applicable, in their simple form, only to bushings built up of homogeneous material, and that they have no bearing at all upon condenser-type bushings.

1. *To Find the best Value of r for a Given Value of R.* The idea that when the external diameter $2\,R$ of the bushing is fixed the best design will be the one in which r is greatest, is misleading. There is, for each given value of R a best value of r, and whether the sheath diameter be made less or greater than the value thus indicated, the stress in the insulation will be increased. This best value of r is given by, $r = R/2.72$, an equation obtained by writing down the condition that $(d\,v/d\,r)$ shall be a minimum. The equation (1) given above shows that $(d\,v/d\,r)$ will be a minimum when

$$\{r \log_e (R/r)\}$$

is a maximum, that is to say, for that value of r which makes $d\,\{r \log_e (R/r)\}\,/\,d\,r = 0$

The solution of this equation is the formula just given,

$$r = R/2.72 \qquad (2)$$

It tells the best value for r when R is given, but it must not be supposed that when r is given this formula tells the best value for R—since, clearly, in this case the value for R which ensures the minimum stress in the insulation is the greatest allowable value.

2. *To Find the Minimum Allowable Value of R when V and (d v/d r) are Given.* This is the form in which the problem usually is presented to the designer.

In equation (1) we now set $(R/r) = 2.72$ and get,

$$\left(\frac{d\,v}{d\,r}\right) = \frac{V}{r \log_e 2.72},$$

and since $\log_e 2.72 = 1$ (because, strictly, the 2.72 should be 2.71828 . . . or "e", the base of the Napierian logarithms) this becomes $(d\,v/d\,r) = (V/r)$, or, calling $d\,v/d\,r$, the voltage gradient at the surface of the sheath, g, the rule becomes

$$r = V/g = R/2.72$$

or

$$R = 2.72\,(V/g)$$

and

$$r = R/2.72 = V/g,$$

For g the designer puts what he considers a safe working value of volts per centimeter for the material of the bushing.

The following is an analysis of published data of bushings; they are not selected but have been taken at random from reputable sources, and in each case it appears that considerable saving in the thickness of the bushing might have been made by decreasing R and increasing r without subjecting the insulation to any greater strain than that which must occur in the bushing actually used.

Material of bushing	Test voltage, volts	As used		Best values	
		R cm.	r cm.	R cm.	r cm.
Oil-filled	177,000	9.5	2.9	9.4	3.45
Micanite and paper	200,000	6	1	4.9	1.8
	160,000	5	1	4.4	1.6
	130,000	5	1	4.4	1.6
	100,000	4	1	3.95	1.45
	50,000	3.4	1	3.35	1.23

Reactors for Electric Furnace Circuits

BY HARRY A. WINNE

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IN any alternating-current circuit supplying power to an electric arc furnace, the reactance of the circuit is depended upon to stabilize the arc, and to limit the maximum current which will flow through the circuit in case the arc becomes short-circuited, due to the electrodes coming into direct contact with each other or with the furnace charge. The resistance of the buses, electrodes and charge will help to limit the maximum current, but its effect is small in comparison with that of the reactance.

It is the purpose of this paper to discuss briefly the various methods of introducing reactance into furnace circuits, but not to attempt to determine what the amount of this reactance should be. This value will vary widely in different installations, and depends upon the limit which must be placed on the maximum current surges in the circuit, always taking into consideration the fact that as the reactance is increased the power factor of the load will decrease.

As a matter of interest is included the curve in Fig. 1 illustrating graphically the relation between reactance and power factor in a circuit. As abscissas are plotted reactance voltages in percentage of the supply voltage, while the ordinates represent the power factor of the circuit in per cent. It might be noted that maximum current can be limited to twice normal value, by using 50 per cent reactance, with a normal load power factor of 86.6 per cent, which is higher than the overall power factor of the load drawn by the average induction motor-driven manufacturing plant. A power factor as high as 95 per cent at normal load can be obtained with an amount of reactance which will limit the maximum current to only slightly more than three times normal.

Incidentally, the ordinates of this curve also indicate the voltage drop due to resistance in the circuit, or, neglecting the resistance in the transformer and furnace leads, the actual voltage which is obtained across the furnace electrodes in per cent of the supply voltage.

In the following discussion the electrical circuit of the installation, or briefly the furnace circuit, is considered as beginning at the circuit breaker which connects the furnace transformer to the power supply line. The total reactance of this circuit is made up of several components namely the reactance of the transformer, of reactance coils if such are used, of the heavy current leads from the transformer to the furnace, including the electrodes, and of the charge itself.

The reactance of the transformer can be varied within limits, as can that of the leads and buses by changing the spacing between and the arrangement of the conductors, but practically there is a minimum value for any given installation below which the reactance cannot be diminished.

This minimum limit increases with increasing current-carrying capacity of the installation, and may actually become a serious handicap on very large furnaces.

However, there are numerous cases in which it is desirable to have a reactance even higher than what may be termed the "normal" value for the circuit. Such conditions may arise with furnaces of small capacity, on steel or other metal melting furnaces in which a high voltage is used for melting and a lower for refining, or when it is necessary to limit the maximum current surges to a very low value. In such instances it becomes necessary to adopt some means for inserting reactance into the circuit.

The means available for this purpose are: to make the transformer of high reactance; to so arrange the heavy current conductors as to obtain the desired effect; or to use external reactance coils on either the high-voltage or low-voltage side of the transformer.

High-Reactance Transformers

The ordinary power transformer has an inherent reactance of from 2 per cent to 6 per cent. This value can usually be increased to a maximum of about 20 per cent without excessively increasing the cost or decreasing the efficiency of the transformer. Consequently, if a reactance of not over 14 per cent to 18 per cent in addition to the normal value is desired *permanently* in the circuit, the transformer manufacturer can usually incorporate it in the transformer.

This method of obtaining additional reactance is only satisfactory if the high reactance is desired under all conditions of furnace operation, and should not be used when it is advantageous to vary the reactance during the operating cycle. Neither is it ordinarily satisfactory on melting furnace installations using different voltages during different portions of the operating cycle, as with the usual system of tapping the transformer high-voltage winding to obtain variable low voltages, the percentage reactance of the transformer is higher for the low-voltage connection than for the high. That is, a transformer designed to give voltages of 120 and 80, and have a reactance of say 10 per cent on the 120-volt connection, might have a reactance of 15 per cent on the 80-volt connection. The effect of this circumstance is decidedly disadvantageous, as the percentage reactance of the buses and cables is greater at the lower voltage,—assuming the same current,—than at the higher voltage, whereas a lower total reactance at the lower voltage would be advantageous.

*Presented at the Boston Meeting of the A. I. E. E., April 9, 1920

Additional Reactance Obtained by Arrangement of Conductors

Another method of obtaining additional reactance, when the same is desired in the circuit continuously, is to arrange the heavy current leads from the transformer to the furnace with a comparatively wide space between those of different phases.

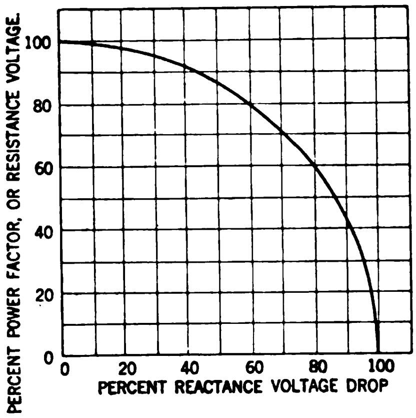

Fig. 1—Relation Between Reactance and Power Factor of a Circuit at Normal Kv-a. Load

Where the current per phase is high and the frequency 60 cycles, a considerable amount of reactance can be obtained in this way. As a matter of fact on furnaces of large capacity it is usually necessary to place the leads very close together, and sometimes interlace them, in order to prevent too high a reactance in the circuit.

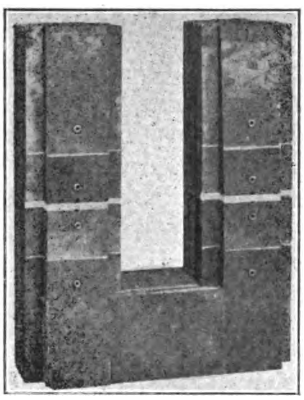

Fig. 2—Core of Iron-Core Reactor
Light Shaded Sections Represent Air Gap

As a consequence it is usually only on smaller furnaces, or furnaces using a high voltage during a portion of their cycle, that special provision for obtaining high reactance is necessary.

External-Reactance Coils

In many electric furnaces melting and refining steel and other metals a higher voltage is used during the melting than during the refining period. Owing to the higher voltage, and to the fact that conditions in the furnace during the melting portion of the cycle are such as to cause frequent current surges, reactance coils are often inserted in the circuit while the higher voltage is being used. These coils may be of either the iron-core or air-core type, and may be connected either in the high-tension supply circuit to the transformer, or between the transformer and the furnace.

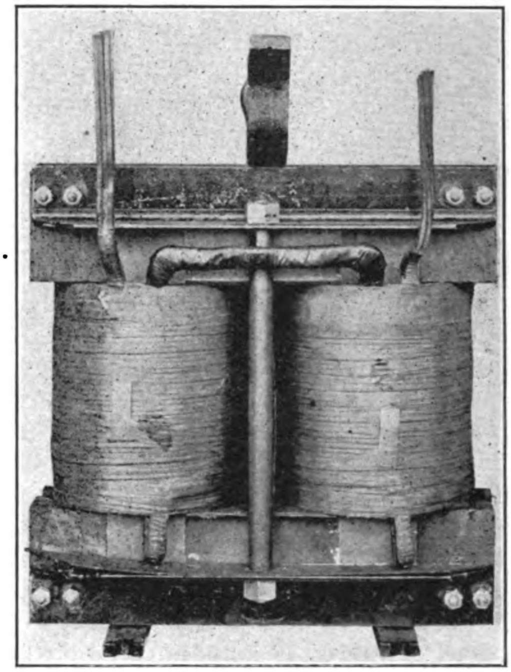

Fig. 3—Iron-Core Reactor Ready for Assembly in Tank

Iron-Core Reactors

The iron-core reactor consists simply of a number of turns of insulated conductor, wound upon a laminated iron core of magnetic structure very similar to a transformer core, except that it usually does not form an ab-

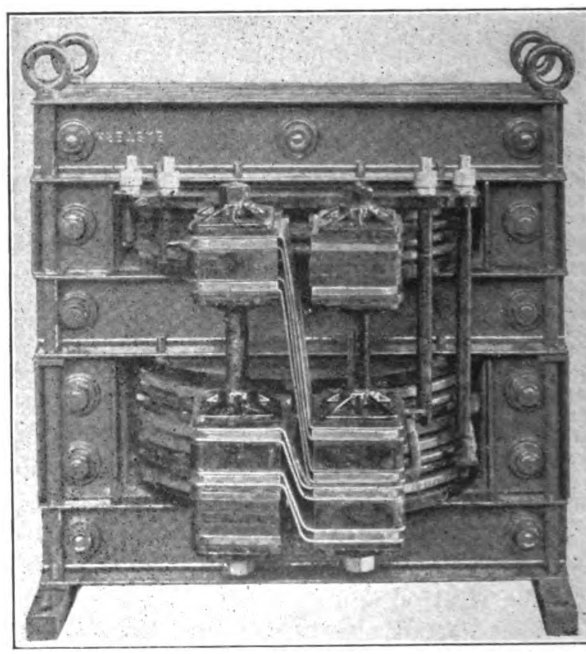

Fig. 4—Special Iron-Core Reactor with Auxiliary Short-Circuiting Winding

solutely closed magnetic circuit, but has a considerable air gap. The air gap improves the operating characteristics of the reactor, helping to reduce the magnetic saturation of the core through the current range for which the reactor is designed. This type of reactor may be air or oil insulated, and is usually self-cooled.

In the design of iron-core reactors which are depended upon to limit the current in a circuit, care must be exercised to insure that the iron core will not be over saturated at the maximum value of current which can

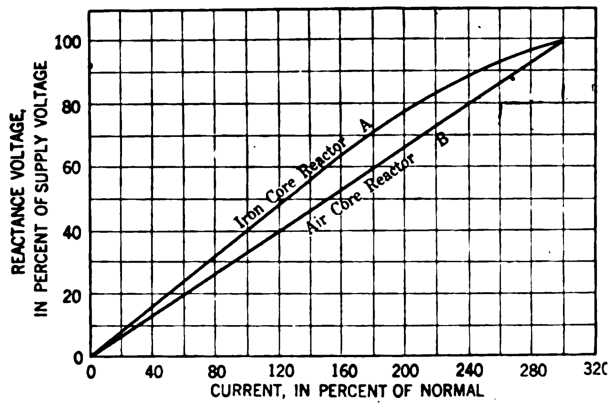

Fig. 5—Characteristic Curves of Iron- and Air-Core Reactors

be forced through the circuit. Otherwise, the effective reactance of the coil will decrease greatly just when its full effect is most needed. A characteristic curve for an iron-core reactor is shown in Fig. 5 curve A. While this coil has a reactance voltage of 40.5 per cent at normal current, it gives only 100 per cent reactance voltage at 300 per cent normal current. That is, while the current has increased to three times normal, the reactance voltage has increased to only 2.47 times normal. Obviously, for current-limiting purposes the iron-core reactor should be designed so that its entire working range will fall below the "knee" of the curve.

The effect of the hysteresis in the iron core is to cause a distortion of the wave of the reactance voltage which is practically equivalent to a time-lag, thereby reducing the effectiveness of the reactor in maintaining the arc as the supply voltage approaches the zero value of its cycle.

The iron-core reactor is chiefly used in circuits carrying currents of less than about 50 amperes, when a reactance of more than 4 or 5 per cent is required. Under such conditions an air-core reactor would require a very large number of turns to give the desired reactance, and the iron-core design is considerably more economical.

A rather unusual iron-core reactor is illustrated in Fig. 4. This particular coil was designed for an installation in which two separate arcs were to be supplied from two separate low-voltage coils on a single transformer. Consequently it was necessary to place the reactor in the low-voltage circuit, the normal current in which was 4000 amperes. Furthermore, it was desired to be able to cut the reactor in and out of the circuit by push button control. As electrically operated circuit breakers of the current capacity required were quite expensive, an auxiliary coil of a large number of turns was wound on the reactor core. Short-circuiting this auxiliary coil had the same effect in the main circuit as short-circuiting the reactor; owing to the turn ratio, the current flowing in the auxiliary coil, when short-circuited, was less than 200 amperes, and an inexpensive contactor could be used.

Air-Core Reactors

Air-core reactors, as the name implies, are coils with no iron or other magnetic material in their flux paths. Two typical methods of instruction of air-core reactors are illustrated. Fig. 6 shows what is termed the "disk-coil" type. This construction is used when a large number of turns are required to give the desired reactance, as in a low-current high-voltage circuit. A number of flat disk-coils of insulated conductors are assembled in a vertical stack and clamped between alloy spiders by means of insulators. The coils are spaced from each other by porcelain insulators, which support them at an angle of about 30 degrees to the horizontal, thus allowing good ventilation and cooling.

A "cast-in-concrete" reactor is illustrated in Fig. 7. In this reactor the conductor, of bare copper cable either solid or stranded, is solidly imbedded in specially

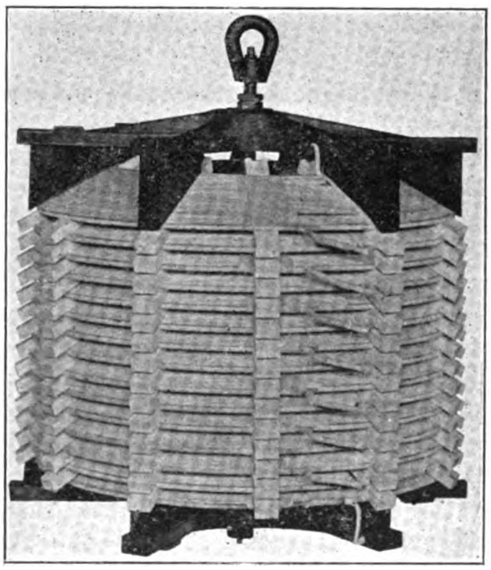

Fig. 6—Air-Core Reactor, Disk-Coil Type, Before Impregnation of Coils

treated concrete supports. The concrete is actually cast in place about the conductor, and is then cured in high-pressure steam, a process which secures a mechanical and electrical strength obtainable in no other way. The conductor and concrete are in very intimate mechanical contact, forming a strong rigid unit.

The vertical supporting members are mounted on a reinforced concrete base, which is in turn supported on

porcelain posts when the circuit voltage is above 1000.

The layers of conductors lie at an angle to the horizontal, alternate layers being dished in opposite directions, so that the space between conductors in adjacent layers increases with the number of included turns, and consequently the voltage, between the conductors.

There is no organic material whatever used in the construction of the cast-in-concrete reactor, consequently it is fire-proof and practically indestructible, except by actual melting of the conductor.

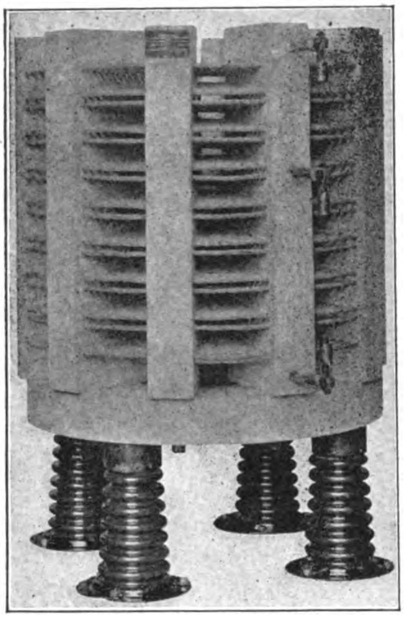

Fig. 7—Air-Core Reactor, Cast-in Concrete Type

The method of construction of the cast-in-concrete reactor does not lend itself readily to a design involving a very large number of turns. Consequently for circuits carrying very low currents the disk-coil air-core or the iron-core reactor is more economical.

There being no iron present in the magnetic circuit of the air-core reactor, its characteristic curve is a straight line; that is, its reactance voltage increases in exact proportion to the current, regardless of the value of the same. Furthermore, as there is no hysteresis, the flux does not lag behind the current but is always exactly proportional to it, and the full value of the reactive effect is realized.

Position of Reactor in Circuit

Reactors may be connected in either the high-tension supply circuit or between the transformer and furnace. Usually, if the current in the low-voltage circuit is of the order of 1500 amperes or higher, it is more economical, considering the cost of reactors, switches and connections, to put the reactors in the high-voltage circuit. This will also depend, however, on the voltage of the circuit and the amount of reactance required. No absolutely general rule can be given.

Conclusions

When reactance in addition to the normal value is required in an electric furnace circuit it may be obtained by increasing the reactance of the transformer, by suitably arranging the conductors, or by inserting reactance coils. The amount of reactance that can be obtained by the first two methods is limited, and they should only be used when the reactance is desired cotinuously in the circuit.

When varying values of reactance are required during different portions of the operating cycle, reactance coils should be utilized. As the reactance is desired principally as a current limit, air-core reactors should be used wherever possible. Obviously, it would be advantageous if the reactance of the coil increased for current values above normal, as it would then be possible to have a fairly high power factor at normal load and still limit the maximum short-circuit current to a low value. The reactance voltage of the air-core reactor increases in direct proportion to the current flowing, while that of the iron-core type increases at a lower rate than the current. Obviously, the air-core reactor is preferable for furnace work.

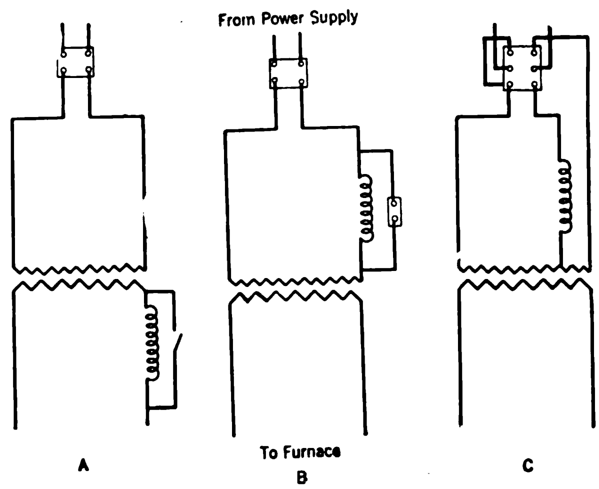

Fig. 8—Various Arrangements of Reactors in Electric Furnace Circuits

In view of the considerations stated above, the cast-in-concrete air-core reactor, being substantial, efficient, and fire-proof, is in the opinion of the writer, the most suitable reactor for electric furnace circuits.

A NEW FUEL FLUID

Jerome Alexander, in a paper read before the American Chemical Society at St. Louis, April 15, announced the discovery of a new fuel fluid, greater in heat value than either coal or present fuel oils. He asserted that the fluid would prove valuable to navigation, permitting a wider cruising radius, and could be used for smoke screens. The new fuel utilizes coal waste and cheap tars, mixed by a secret process.

Automatic Control of Arc Furnace Electrodes

BY J. A. SEEDE

Engineer, General Electric Co., Schenectady, N. Y.

ALL electric furnaces with the exception of a certain special type of resistance furnace, the induction furnace, require electrodes for conducting current to the active zone. These electrodes are either fixed or movable and, with very few exceptions, are made of carbon or graphite.

In those furnaces using fixed electrodes, as in a graphitizing furnace, or in certain smelting furnaces, where the electrodes are moved only at long intervals as in an iron smelting furnace, the power input is controlled by varying the voltage applied to the electrodes by one of several available methods.

The most important class, at least from the standpoint of numbers, comprises those furnaces of the arc type in which control of the power input is obtained by moving the electrodes up and down, or in and out, as the case may be. These may be divided into two classes; the first embracing furnaces operating on a continuous cycle and normally of comparatively large capacity, such as calcium carbide and various ferro alloy furnaces; the second comprising furnaces for melting steel and other metals which operates on an intermittent cycle and range normally in capacity from 4500 kw. to 75 kw. and smaller.

The power input of furnaces of the first class may easily be kept within 1 per cent either side of the average while several times this value must be allowed furnaces of the second class, especially in the case of steel melting.

The various electric furnaces for melting and refining may be grouped in the following divisions:

Case 1—One Movable Electrode—One Arc

For the control of one electrode all that is required is a single contact-making current relay with auxiliary contactors, relays, etc. On circuits with excessive voltage fluctuations or where furnace troubles are experienced from careless operators and poor scrap, additional protection may be desirable, such as may be obtained by addition of a balanced voltage relay. In this division may be grouped single electrode furnaces for various smelting applications, the single-phase Girod and Snyder steel melting furnaces and the Booth, Detroit, and Weeks brass melting furnaces.

Case 2—Single-phase Two Movable Electrodes—Two Arcs In Series

With this arrangement current control of both electrodes might quickly result in one arc absorbing all the voltage and forcing the other electrode into the charge, destroying the heat balance and radiating too much heat to the wall. To prevent this we control one electrode by current in that electrode and the other electrode by the voltage drop across the arc. The first control virtually adjusts the total length of both arcs while the second control maintains constant the length of the second arc. In case of variable voltage control another feature is required to maintain the arc voltage constant at one-half total voltage, that is a balanced voltage relay.

This division comprises single-phase, two-electrode smelting furnaces and the single-phase Heroult furnace.

Case 3—Two-Phase—Two Movable Electrodes—Two Arcs

This is the well known connection of using two-phase, three wires, or its electrical equivalent, the bottom being the neutral. This arrangement uses practically the same control as two single-phase furnaces, each having one movable electrode, in one shell and therefore requiring two current relays.

In this division are the Snyder, Greene, Gronwall-Dixon, Vom Baur, Rennerfelt and Greaves-Etchells melting furnaces.

Case 4—Two-Phase—Four Movable Electrodes—Two Arcs In Series Per Phase

This arrangement is electrically the same as Case 2, having two groups in one shell. The Stobie steel melting furnace is practically the only representative of this class.

Case 5—Three-Phase—Three Movable Electrodes—All Arcs In Series

As all electrodes are above the charge equal current will give balanced voltage and power, three current relays being sufficient. In this division are almost all three-phase smelting furnaces and the three-phase Heroult and Stassano furnaces.

Case 6—Three-Phase—Three Movable Electrodes—With Bottom Connections

In this case control will be obtained by having three elements of case 1, that is, practically three single-phase furnaces in one shell. This connection is almost wholly limited to the three-phase Girod melting furnace and special smelting furnaces.

While close control of the power input is desirable, there are other factors to be considered, such as furnace maintenance, electrode consumption, quality of product and unecessary labor charges, in addition to strains on generating and transforming apparatus, all of these being improved by using automatic electrode control. It is admitted that attempts have been and will be made to control furnaces by hand, but a brief consideration of some of the inherent disadvantages of hand control should convince any operator of the false econ-

Presented at the Boston Meeting of the A. I. E. E., April 9, 1920.

omy of such arrangement. These factors might be listed as follows:

1. Power Input.
2. Furnace Maintenance.
3. Electrode Consumption.
4. Labor Charges.
5. Quality of Product.
6. Upkeep of Transformers.

All of these items successfully combined have bu one meaning that is, continuous operation with a minimum of interruptions and accordingly, minimum operating costs.

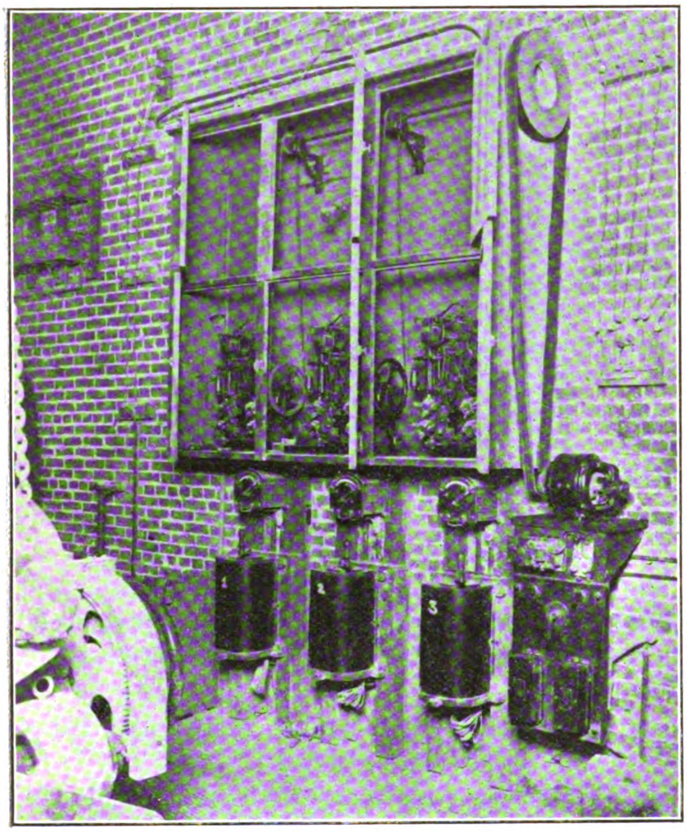

Fig. 1—Three-Phase Thury Regulator

1. *Power Input.* In operating an electric furnace it is desirable to keep all surges, momentary and sustained, within the closest reasonable limits, as in practically all cases these surges have a definite bearing on the cost of power and, even when this effect is a minimum, undue surges affect other power consumers on the same line and frequently result in complaints which tend to cause prejudice against electric furnaces in general. These surges also affect other items such as, furnace maintenance, electrode consumption, quality of product and upkeep of apparatus, all of which are of sufficient importance to warrant systematic efforts to reduce this evil to a minimum. The momentary surges are limited by the electrical characteristics of the circuit while the duration of the sustained surge is determined by the operation of the automatic control.

In those power contracts where power is purchased at a fixed price, the importance of keeping the load factor close to 100 per cent need not be emphasized and this has a direct bearing on the production that can be obtained from a given equipment. In any installation, there are a number of fixed charges and the higher the load factor the lower will be the amount of these charges per unit of material produced.

2. *Furnace Maintenance.* The effect of sustained surges is to carry the current density far above the designed carrying capacity of the electrode holders and conductors. As the heating varies directly with the square of the current, a current increase of 50 per cent will increase the heating 125 per cent above normal and shorten the life of any current-carrying contact surface. The heat that is radiated directly from the arc to the roof and side walls when the electrodes are raised, unnecessarily shortens the already brief existence of those important furnace parts.

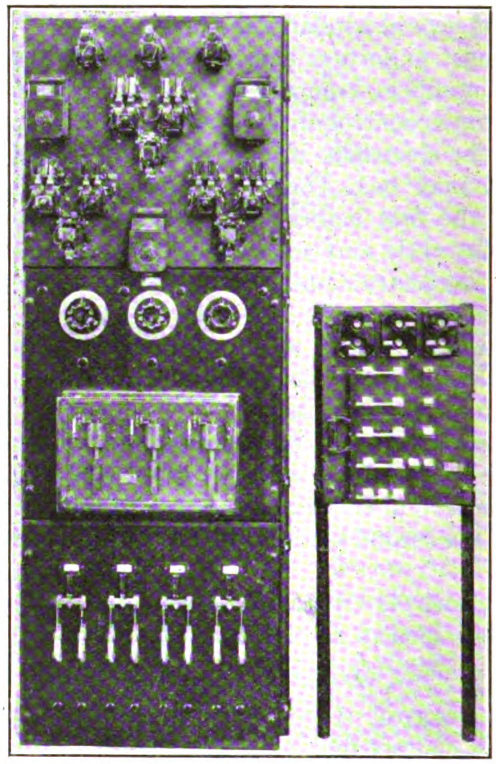

Fig. 2—Three-Phase General Electric Regulator

3. *Electrode Consumption.* There seems to be little question that electrode consumption is increased when the power is permitted to vary over wide ranges. Excessive or long continued surges tend to cause overheating at the weak spots in the electrode with consequent spalling and cracking.

4. *Labor Charges.* In these times when all labor is scarce and high-priced, the practise of paying a man 50 cents an hour to sit on a stool watching one or more meters and manipulating controlling devices in an attempt to keep the power input within reasonable limits is an economic waste that can have no reasonable defense. No matter how sincere the worker may be

in his attempt to meet conditions imposed, he is, after all, only human and his will soon becomes deadened by the tiring effect of watching a meter needle in constant motion.

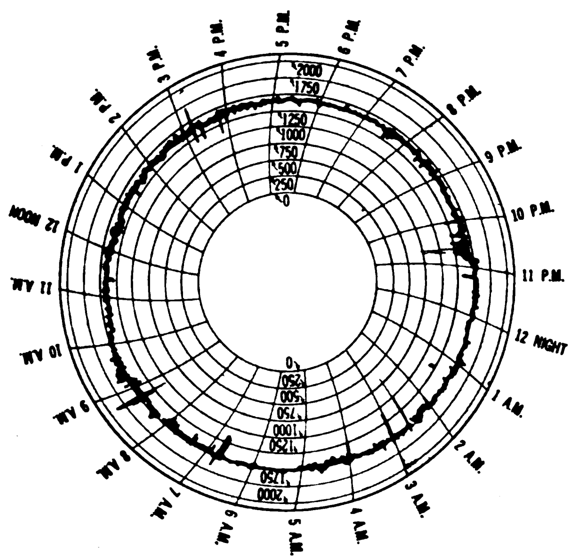

Fig. 3—Twenty-four Hour Chart of Three-phase, 1500 kw. Ferro-Chromium Furnace Controlled by General Electric Regulator

Assume that he can keep his eyes fixed continuously on the needle (which is hardly possible) and there is a sudden change in the furnace. The eye conveys the message to the brain, the brain sends an impulse to the hand, the hand turns a wheel or throws a switch and

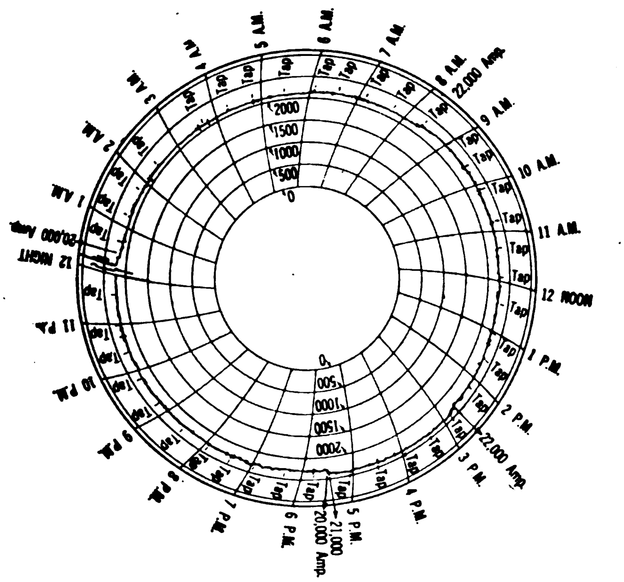

Fig. 4—Twenty-four Hour Chart of Three-phase, 3000. kw. Calcium Carbide Furnace Controlled by General Electric Regulator

the electrode position is regulated, all of which takes appreciable time and if he happens to be sleepy or looking in some other direction, the adjustment is accordingly delayed.

With the contact-making meter following the impulses continuously, the automatic regulator throws the switch as soon as the change takes place and the electrode is moved almost instantly. Assuming that an operator can manage two or more electrodes (which is true only in unusual cases), with continuous operation, at 50 cents per hour there will be a labor charge at the end of the year over $4000, an amount that will pay for several automatic electrode regulators.

5. *Quality of Product.* The effect on the quality of the product will vary with different processes but in certain cases, such as steel melting, it would only require plunging the end of the electrode in the bath several times to add enough carbon to upset the analysis and cause considerable delay in bringing it back to the desired point. Also if the electrodes contained certain impurities these could be transferred to the steel and cause additional trouble.

In addition the long flaring arc that exists when the electrode is raised too high will volatilize part of the slag which will condense on the roof and side walls and assist in their destruction by fluxing.

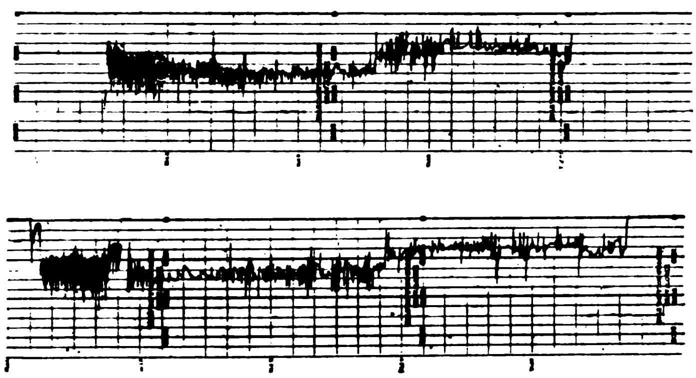

Fig. 5—Two Charts of Heats in 1500-kw. Three-phase. Steel-Melting Furnace Starting with Cold Charges

6. *Upkeep of Transformers.* While the average transformer stands considerable abuse it has its limitations and will be in better shape to meet emergency conditions if it has not been subjected to the strains and overheating of a large number of surges.

General

The problem of maintaining the position of an electrode with its supporting mechanism and flexible conductors is not a simple one even against another stable electrode, be it the surface of a molten charge or another carbon or graphite electrode, and when the second electrode is the surface of a heap of various pieces of solid metal, continually changing under the action of the arc, the difficulties are considerably increased.

There is considerable difference whether or not the metal is molten or solid. From the surface of molten metal there is a continuous spray of small metallic particles which make it a simple matter to establish the arc sometime before the electrode touches the metal, but with solid metal the electrode must practically

touch the charge before the arc is struck and then the electrode must be drawn away quickly so as to minimize the surge that invariably follows. This is the condition met in the first part of melting down a charge of steel scrap and is a trying time to all parts of the equipment, but is also the time when the automatic control pays for itself many times.

To accomplish these results and keep the power input within set limits means an apparatus that will move

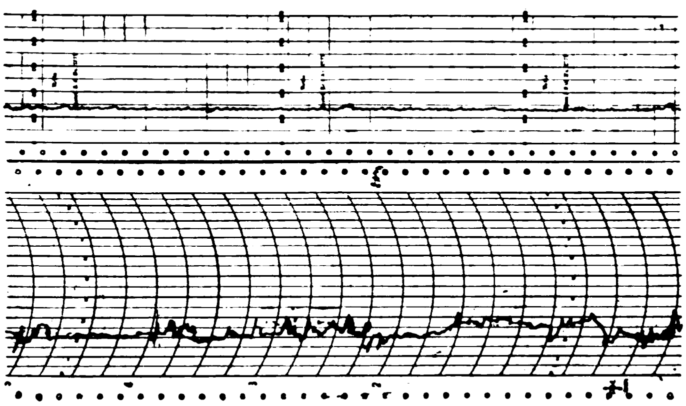

Fig. 6—Comparative Charts of Similar Furnaces, the Lower One, Using Hand Control and the Upper One Automatic Control, Furnace Quiet

the electrode quickly from the old position to the new one and then manitain the new position without overrunning. To do this without extraordinary stresses on the apparatus means average electrode speeds of approximately 12 in. per minute, or less. This is considered normal automatic operation but abnormal or emergency operation, such as changing a broken electrode during a heat, a hand-operating speed of three to ten times this figure is desirable, if not absolutely necessary.

There are two methods of electrode regulation, the intermittent, in which the electrode is moved by a series of small movements, and the continuous, in which the electrode is adjusted in one continuous motion and then stopped. The Thury regulator belongs to the intermittent type while the General Electric regulator is of the continuous type, and both types have attained considerable success in the automatic control of arc furnace electrodes.

The apparatus used consists substantially of the following:

For each electrode there is provided a balanced relay, with adjustable damping, which is responsive to electrical changes in the furnace and controls, mechanically or electrically, the circuits of the motor having that electrode. The successful functioning of the control depends initially on a balanced relay, usually responsive to amperes but often to volts and occasionally to watts. This relay is provided with a dash pot which can be adjusted to vary the damping as may be required in different applications.

In the Thury regulator this relay engages a mechanical device for controlling the circuits of the electrode motor.

In the General Electric regulator this relay is provided with contacts, which control solenoid operated switches which in turn control the electrode motor circuits.

Safety devices giving additional protection against exterior disturbances are desirable, and one arrangement consists of shunt relays, excited by the voltage drop between electrodes and so arranged that upon failure of the furnace power supply the automatic control will be rendered ineffective and prevented from forcing the electrodes into the charge and causing damage to the apparatus.

This is done because the power supply to the electrodes and to the motor-generator sets supplying direct-current power are usually separate, and with the failure of the power supplied the electrodes, the automatic control would necessarily force the electrodes into the charge. By a simple connection this feature is rendered ineffective when the hand control is used so that the electrodes can be moved at will, regardless of the condition of the power circuit supplying the electrodes.

As stated before, the electrode movement must be positive, especially as to stopping, and this is preferably done by dynamic braking for which purpose a shunt-wound motor is preferred. It is understood that alter-

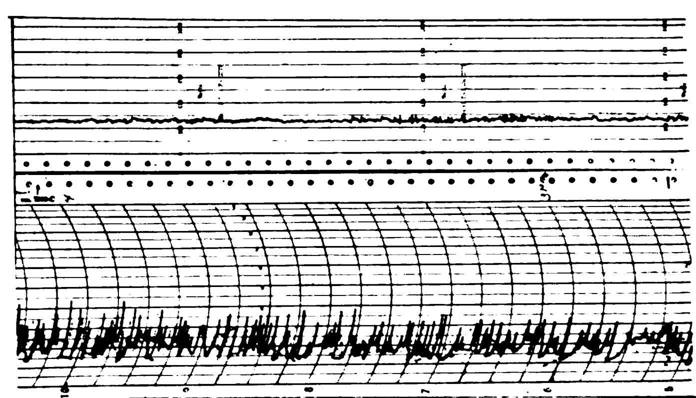

Fig. 7—Comparative Charts of Similar Furnaces, the Lower One Using Hand Control and the Upper One Automatic Control, Furnace Active

nating-current motors have been used for the successful control of electrodes, but this means solenoid brakes, and with all due respect to the perfection attained in those devices it is an additional feature that requires upkeep and is therefore opposed to the minimum simplicity.

The direct-current motor requires a source of d-c. power which may mean the added complexity of an added motor-generator set, but this is a small matter and usually direct-current power is available from a crane circuit.

The suggestion has been made that the furnace equipment would be simplified by operating alternating-current electrode motors from furnace circuits,

but this is not feasible for many reasons, such as drop in voltage with surges, rendering the motor weakest when needed, requiring voltage to be on electrodes when making electrode changes, etc.

With a reversing three-phase motor there would be required five wires per motor and the wiring for the brake solenoids, while with the d-c. motor four wires are required and no brake wiring.

The automatic control of the electrode is affected somewhat by power factor and occasionally references are made to furnaces operating with a power factor of 95 per cent. The normal furnace load is so much better than what is expected of industrial apparatus in general that we may reasonably protest against expecting such high figures and refer to the better results that will be obtained by arranging for approximately 90 per cent power factor. Many power companies are now penalizing power factors below 70 per cent, but such low power factors are not desirable for ordinary furnace work.

With 95 per cent power factor the reactance component is 31.2 per cent which gives a short-circuit current of 320 per cent. With 96 per cent power factor these figures are 43.6 per cent and 229 per cent respectively, while with 85 per cent power factor the corresponding figures are 52.7 per cent and 190 per cent. This means that the surges are 40 per cent higher on 95 per cent power factor over 90 per cent power factor and 20 per cent higher on 90 per cent as compared to 85 per cent power factor. From this it can be seen that 90 per cent power factor gives results that are a good compromise on surges and reactive component and it is recommended that this figure be kept in mind on all furnace installations, especially in small capacities.

The automatic electrode regulator has been used commercially in Europe for 25 years, and in this country about 15 years. Almost invariably it demonstrates to the user its value in effecting unforseen savings and bettering conditions, not the least being the maintaining of co-operation with the power company. With constantly increasing demands for power and increasing difficulty in meeting these demands, limitations must be maintained on power users and accordingly, with furnace users, the automatic electrode regulator will become more and more, a factor of first importance in the great field of electric arc furnace applications.

"REPRODUCTION NEW" MEANS HIGHER RATES

Possibility of rate increases of nearly 100 per cent for all public utility operators is seen in the decision of the United States Supreme Court upholding the "reproduction new" as the valuation basis for fixing railroad rates. The decision was made in the case of the Kansas City Southern Railroad against the Interstate Commerce Commission. According to press dispatches from Washington, the Supreme Court held the present value of physical property of the railroad should be accepted as the basis for determining rates. In most cases physical property of railroads, street car, telephone, electric light and power and gas companies of the country would cost nearly double their original values if reproduced today. Property value is the largest item considered in rate fixing. Other items are operating cost and percentage of profit. From the valuation must be deducted the amount of depreciation.

In fixing the new schedule of rates for Bell telephone companies operating in Indiana the public service commission recently refused to accept the "reproduction new" basis offered by the company, but based the new rates on the reproduction values of companies' various physical properties throughout a period of five years. Many other rate cases have been decided by the commission on the same basis.

Conditions similar to those created in Indiana by the basis established by the Supreme Court exist in various other states. Little doubt is entertained by rate experts that the railroad decision will be so far-reaching as to affect every form of industry over which a government institution possesses rate-making authority.

Value of rolling stock of the Kansas City Southern Railroad was not offered for consideration by the Supreme Court, according to dispatches, but the court found for the appellant on its present-day cost of right-of-way and terminals contention.

The Indiana commission has followed the rule established in several other states of basing valuation estimates on an average of production costs throughout a period of five years. In the case of the Bell telephone companies the commission took an average of production costs in the years from 1913 to 1918. Present-day material prices were held by the commission to be abnormal, and, therefore, not suitable to the formation of a sound rate-fixing estimate.

It is difficult to foresee the results of the establishment of the new basis of valuations. As far as rates are concerned it is quite clear that the "reproduction new" values of nearly all utilities would make rates nearly double present rates if a profit margin of 7 per cent is maintained.

If a telephone company's property cost $100,000 five years ago, it is worth today $200,000 in a fair round figures estimate, it is asserted. That is, it would cost that much to reproduce it today. Without confusing the figures with depreciation expense, rates for that company, based on the original valuation, would amount to 7 per cent of $100,000, plus the cost of operation. That would mean upward of $7,000. The same percentage of profit on a $200,000 valuation would mean about $14,000, plus the cost of operation, which would be the same under either valuation. Thus it is seen that the new valuation as against the old system would mean rate increases of more than 95 per cent. Even in cases where the five-year-period valuation basis is used, the new valuation would mean rate increases of more than 75 per cent, experts say.—*Telephone Engineer*.

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THIRTY-SIXTH ANNUAL CONVENTION

The Thirty-Sixth Annual Convention of the American Institute of Electrical Engineers will be held at "The Greenbrier," White Sulphur Springs, West Virginia, June 29 to July 2, 1920.

In both the selection of the convention headquarters and in the program proposed the Convention Committee feels that the Annual Convention for 1920 should prove a fitting climax to an Institute year of unprecedented activity and advancement. Seven technical sessions are scheduled at which subjects of particular interest in many phases of present day practise will be presented through the medium of a most comprehensive collection of papers. Ample opportunity has also been provided for recreation and entertainment by leaving the afternoons open for the many entertainment features which are being arranged by the Convention Committee, including dancing, teas, card parties and other special functions for the ladies, and the usual golf and tennis tournaments, baseball and other special events.

Location

The selection of White Sulphur Springs as the convention meeting place is a most happy one. It is located equally distant in an air line from New York, Toronto, Chicago, St. Louis and Atlanta. Amid a peculiarly attractive environment on the slope of the Greenbrier Mountains, 2000 feet above sea-level, where it is never hot even in mid-summer, is situated "The Greenbrier," a new and magnificent hotel of modern steel construction, absolutely fireproof and equipped with every convenience. Every room is connected with a private bath. For those desiring quiet, there are 60 small cottages surrounding the hotel. In close proximity to the hotel there is an 18-hole golf course, 6250 yards long, one of the finest in the country, and an equally good nine-hole course. The new clay tennis courts are famed the country over. The new bath establishment is luxurious and complete. Every facility is offered guests to enjoy the same kind of baths as are given at European resorts. There is a fully equipped swimming pool, 50 by 100 feet. Over 100 miles of well-built track winding in and out through the mountain ridges lead those interested in horses and riding through some of the most beautiful scenery in the State. A fine stable is maintained, with thoroughbred hunters, jumpers, and horses for all occasions and there is a pack of hounds for drag hunts. Those interested in motoring will find the roads leading through White Sulphur Springs in excellent condition and motoring from New York, Philadelphia and Washington is steadily increasing.

Convention Sessions

A tentative program has been arranged which calls for the opening of the Convention on Tuesday morning, June 29, with the Annual Presidential Address, by President Calvert Townley, followed by the introduction of the President-elect. The remainder of the session will be devoted to the presentation and discussion of the Annual Reports of the Technical Committees. Six sessions for the presentation of papers under the auspices of various technical committees have been mapped out as indicated in the program of sessions.

TENTATIVE PROGRAM OF TECHNICAL SESSIONS

Tuesday, June 29—Opening Session:

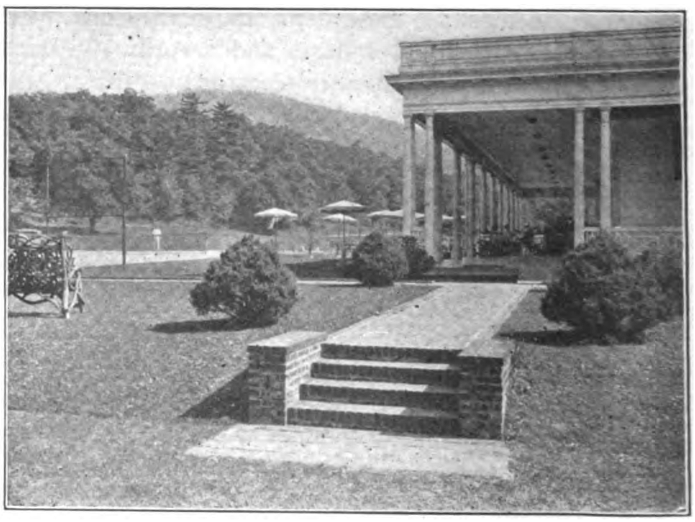
1. *President's Address*, by Calvert Townley.
2. *Report of Technical Committees.*

Wednesday, June 30—Electrical Machinery Session:

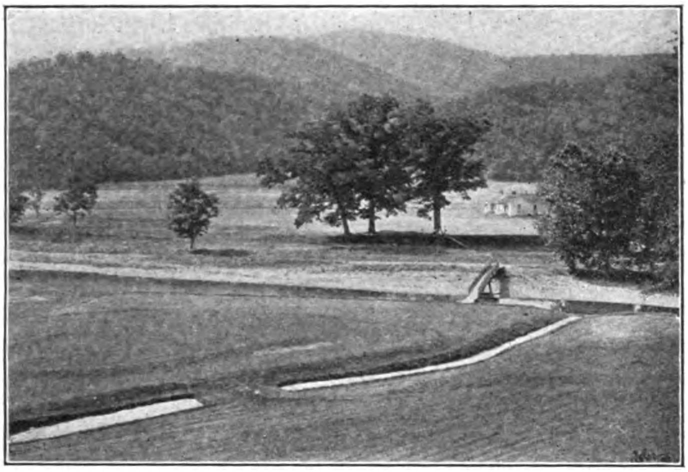
3. *Classification of Large Steam Turbo Generator Failures* by Philip Torchio.
4. *Ventilation and Temperature Problems in Large Turbo Generators* by B. G. Lamme.
5. *Temperatures in Large A-C. Generators* by W. G. Foster.
6. *Some Practical Experience with Embedded Temperature Detectors in Large Generators* by C. J. Fechheimer and F. D. Newbury.
7. *Eddy Current Losses in Armature Conductors* by R.E.Gilman.

Miscellaneous Session:

8. *The Corona Voltmeter and the Electric Strength of Air* by J. B. Whitehead and T. Isshiki.
9. *Reactive Power and Magnetic Energy* by Joseph Slepian.
10. *Theory of Speed and Power Factor Control of Large Induction Motors by Neutralized Polyphase Alternating-Current Commutator Machines* by John I. Hull.
11. *High-Tension Insulator Porcelain* by W. D. A. Peaslee.



TENNIS COURTS AND CLUB HOUSE AT "THE GREENBRIER"



On the Links at "the Greenbrier"

Thursday, July 1—Protective Devices Session:

12. *The Use of Reactors on Large Central Station Systems* by R. F. Schuchardt.
13. *Stability of High-Power Generating Stations* by C. P. Steinmetz.
14. *Voltage Stresses in Reactors in Service* by F. H. Kierstead and Royal Meeker.
15. *Calculation of Magnetic Force on Disconnecting Switches* by H. B. Dwight.
16. *Stresses in Conductors Carrying Heavy Currents* by I. W. Gross.

Electric Welding Session:

17. *Design of Constant-Current Generators for Arc Welding* by K. L. Hansen.
18. *Automatic Arc Welding Apparatus* by S. R. Bergman and H. L. Unland.
19. *Arc Welding Machines of the Wilson Welder and Metals Company* by Alex. Churchward.
20. *Characteristics and Performance of Arc Welding Machinery* by A. M. Candy.
21. *Arc Welding Machinery of the U. S. Light and Heat Corporation* by W. H. Turbayne.
22. *Recent Developments in Electro-Percussive Welding* by D. F. Miner.

Power Factor Session:

23. *Report of Joint Committee.*
24. *Polyphase Power Factor* by F. C. Holtz.
25. *Power Factor Improvement Dependent upon Adequate Metering* by Will Brown.
26. *Power Factor in Polyphase Systems* by F. B. Silsbee.
27. *Power Factor and Unbalance on a Polyphase System* by C. J. Fechheimer.
28. *Polyphase Power Factor* by H. L. Wallau.
29. *Polyphase Power Factor* by P. M. Lincoln.
30. *Polyphase Power Representation by Means of Symmetrical Coordinates* by C. L. Fortescue.
31. *Measurement of Power Factor on Unbalanced Polyphase Circuits* by R. D. Evans.
32. *Polyphase Power Factors and Unbalanced Loads* by Philip Torchio.
33. *Power Factor in Polyphase Circuits* by W. H. Pratt.

Friday, July 2—Excitation Session:

34. *Considerations Which Determine the Selection and General Design of an Exciter System* by J. T. Barron and A. E. Bauhan.
35. *Factors in Excitation Systems of Large Central Station Steam Plants* by A. A. Meyer and J. W. Parker.
36. *Exciters and Systems of Excitation* by H. R. Summerhayes.
37. *The Application of D-C. Generators to Exciter Service* by C. A. Boddie and F. L. Moon.
38. *Exciter Practise in the Northwest* by J. D. Ross.
39. *Generator Excitation Practise in the Hydroelectric Plants of the Southern California Edison Company* by H. H. Cox and H. Michener.

Abstracts of most of the Convention papers appear elsewhere in this issue of the Journal. Papers scheduled for the Miscellaneous session were printed in full in the May Journal.

Advance copies of complete papers may be obtained as soon as available by applying at Institute headquarters.

Transportation

While the following daily schedule is now in effect and will probably remain so until after the Convention, members are advised to consult their local ticket agents relative to trains and fares to and from White Sulphur Springs. Particular emphasis is placed upon the necessity for engaging Parlor Car and Sleeping Car accommodations at the earliest possible date.

Lv. New York, via Penn. R. R.	3.38 p. m.
Lv. West Phila. via Penn. R. R.	5.56 p. m.
Lv. Washington via C. & O. R. R.	10.15 p. m.
Ar. White Sulphur Spgs.	7.05 a. m.
Lv. Norfolk, Va. via C. & O. R. R.	9.00 a. m.
Lv. Richmond, Va. via C. & O. R. R.	1.00 p. m.
Lv. Charlottesville via C. & O. R. R.	4.35 p. m.
Ar. White Sulphur Spgs.	7.05 a. m.
Lv. Chicago, Ill. via Big Four	12.55 p. m. C.T.
Lv. St. Louis, Mo. via Big Four	12.00 noon C.T.
Lv. Indianapolis, Ind. via Big Four	6.15 p. m. C.T.
Lv. Cincinnati, O. via C. & O. R. R.	9.00 p. m. C.T.
Ar. White Sulphur Spgs.	8.30 a. m. E.T.
Lv. Detroit, Mich. via M. C. R. R.	11.30 a. m. C.T.
Lv. Toledo, Ohio via Big Four	1.20 p. m. C.T.
Lv. Cleveland, Ohio via Big Four	11.05 a. m. C.T.
Lv. Cincinnati, O. via C. & O. R. R.	9.00 p. m. C.T.
Ar. White Sulphur Spgs.	8.30 a. m. E.T.

C.T. = Central Time E.T = Eastern Time.

Pullman equipment is being operated daily from Chicago, Indianapolis, Cincinnati, Louisville, New York, Philadelpiha, Baltimore, Washington, and Richmond to White Sulphur and accommodation should be arranged well in advance.

Fares

To White Sulphur Springs from	One Way	Round Trip
New York	$14.22	$25.60
Chicago	19.15	32.30
Cincinnati	10.60	17.18
Pittsburgh	13.15	23.67
St. Louis	19.92	35.86
*Atlanta	17.79	34.14
Detroit	14.80	26.64
Washington	7.37	14.40

These fares do not include War Tax.

Sleeper and Parlor Car charges are additional.

*Via Lynchburg.

Rates at "The Greenbrier"

American Plan

Single Rooms	Two or More sharing bath	Two or More in Room without bath
$10.00 per day	$9.00 per day	$7.00 per day

Reservation of Accommodations

Accommodations at "The Greenbrier" should be reserved as early as possible, by writing or telegraphing directly to the hotel. All communications should be addressed to: "The Greenbrier," White Sulphur Springs, W. Va.

PACIFIC COAST CONVENTION

The Ninth Annual Pacific Coast Convention of the A. I. E. E. will be held in Portland, Oregon, July 21-24, 1920, under the auspices of the Portland Section. Headquarters at the Multnomah Hotel.

A tentative program has been arranged as follows:

Wednesday, July 21

9:30 A. M.

1. *Address* by President Calvert Townley.
2. *Factors Controlling the Design and Selection of Suspension Insulators*, by W. D. A. Peaslee, Electrical Engineer, Jeffery-Dewitt Insulator Company.

2:00 P.M.

3. *Unit Voltage Duties in Long Suspension Insulator Strings*, by Professor Harris J. Ryan and H. H. Henline of Leland Stanford Jr. University.
4. *Electrical Characteristics of the Suspension Insulator at the Higher Voltages*, by F. W. Peek, Jr., Consulting Engineer, General Electric Company, Pittsfield, Mass.

7:30 P.M.

Automobile tour over scenic boulevards of the city.

Thursday, July 22

9:30 A.M.

5. *Electrification of Railroads*, by Reinier Beeuwkes, Electrical Engineer, C. M. & St. P. Railroad.
6. *Bridge Methods for Alternating-Current Measurements*, by D. I. Cone, Engineering Dept., Pacific Telephone and Telegraph Company.

2:00 P. M.

7. *Sawmill Refuse, Fuel Oil and Pulverized Coal*, by Darrah Corbet, Chas. C. Moore and Company.

7.30 P. M.

General discussion on Institute Welfare.

Friday, July 23

9:30 A. M.

8. *Power Factor Correction on Distribution Systems*, by D. M. Jones, General Electric Company, Schenectady, N. Y.
9. *Use of Special Steels in Pressed Steel Transmission Line Fittings*, by L. R. O'Neill, Chief Engineer, Maryland Pressed Steel Company.

In addition to the presentation of the papers scheduled above the Convention Committee has arranged for various entertainment features including a Golf Tournament for the John B. Fisken Cup to start at 1 p.m. on Friday, a trip over Columbia River Highway starting at 2 p.m. on the same day and followed by a banquet at the Crown Point Chalet at 7. p.m.

Saturday, July 24

Tours of inspection to the steam and hydroelectric plants of the Portland Railway, Light and Power Company and the Northwestern Electric Company and to other points of interest in and around Portland are arranged for Saturday July 24.

Special entertainment will be provided for the visiting ladies.

ANNUAL MEETING AND EDISON MEDAL PRESENTATION

The annual meeting of the A. I. E. E. was held at Engineering Societies Building, New York, on Friday evening, May 21, 1920, President Calvert Townley presiding.

The annual report of the Board of Directors was presented in abstract by Secretary Hutchinson. Pamphlet copies of this report had been printed in advance and are available to any member upon application to the Secretary of the Institute.

The report of the Committee of Tellers on the election of officers was then presented and in accordance therewith President Townley announced the election of the following officers, whose terms will begin August 1, 1920: *President*, Arthur W. Berresford, Milwaukee; *Vice Presidents*, E. H. Martindale, Cleveland, Charles Robbins, Pittsburgh, C. S. Ruffner, New York, C. E. Magnusson, Seattle, C. S. McDowell, U. S. Navy, L. T. Robinson, Schenectady; *Managers*, E. B. Craft, New York, Harold B. Smith, Worcester, James F. Lincoln, Cleveland; *Treasurer*, George A. Hamilton, Elizabeth. These officers, together with the eleven holdover members, will constitute the Board of Directors for the year beginning August 1st.

The report of the Committee of Tellers upon the ballots cast by the membership on the proposed constitutional amendments was then presented. These proposed amendments provided that the membership be grouped into geographical districts and that one Vice President be elected from each district for a term of two years.

The report shows that 3936 ballots were cast in favor of the amendments and 36 in opposition. President Townley thereupon declared the amendments adopted. Accordingly, they will become effective in connection with the election in the spring of 1921.

The Edison Medal presentation ceremonies followed immediately after. The program consisted of a statement regarding the origin and history of the Edison Medal by Dr. Carl Hering, Chairman of the Edison Medal Committe, an address relating to the achievements of Mr. W. L. R. Emmet, the medalist, by Past-President H. W. Buck, the presentation of the medal by President Townley and the response of Mr. Emmet. A more detailed report will be published later.

REPORT OF COMMITTEE OF TELLERS ON ELECTION OF OFFICERS

To the President,

American Institute of Electrical Engineers.

DEAR SIR:

This committee has carefully canvassed the ballots cast for officers for the year 1920–1921. The result is as follows:

Total number of ballot envelopes received		4064
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34, of Constitution	74	
Rejected on account of voter being in arrears for dues on May 1, 1920, as provided in the Constitution and By-laws	88	
Rejected on account of ballot not being enclosed in inner envelope, or being improperly marked, or on account of inner envelope bearing an indentifying name, according to Art. VI, Sec. 34, of the Constitution	11	
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI. Sec. 34, of the Constitution	39	
		212
Leaving as valid ballots		3852

These 3852 valid ballots were counted, and the result is shown as follows:

For President

A. W. Berresford	3007
C. E. Skinner	479
William McClellan	87
A. M. Schoen	84
N. A. Carle	82
J. B. Fisken	18
Blank	95

For Vice-Presidents

E. H. Martindale	3536
Charles Robbins	3512
C. S. Ruffner	3462
C. E. Magnusson	3433
C. S. McDowell	3352
L. T. Robinson	3307
J. B. Whitehead	519
Philip Torchio	376
H. P. Liversidge	295
W. S. Lee	290
*Robert Sibley	70
Blank	960

*Candidate withdrew prior to printing of ballots.

For Managers

E. B. Craft	3715
Harold B. Smith	3710
James F. Lincoln	3698
Blank	433

For Treasurer

George A. Hamilton	3724
Blank	128

Respectfully submitted,

(*Signed*) EDW. J. K. MASON
Chairman

WILLIAM P. ABENDROTH
CHAS. M. FULK
P. C. PAQUETTE
PHILANDER NORTON

REPORT OF COMMITTEE OF TELLERS ON AMENDMENTS TO THE CONSTITUTION

To the Board of Directors,
American Institute of Electrical Engineers.

GENTLEMEN:

This committee has canvassed the ballots cast on the amendments to the Constitution submitted to the membership in a circular letter dated March 15, 1920, and the result is as follows:

Total number of envelopes received		4508
Of these the following were rejected in accordance with the Constitution and By-laws for the reasons given below:		
No identifying name on envelope	380	
In arrears for dues on May 1, 1920	76	
Received after May 14, 1920	1	
Blank ballots	7	
Ballots rejected because of improper marking, etc.	72	
Total invalid ballots	536	
Leaving as valid ballots		3972

These valid ballots were counted and the result is as follows:

In favor of adoption of amendments	3936
Against adoption of amendments	36

Respectfully submitted,

Committee of Tellers.

(*Signed*) EDW. J. K. MASON,
Chairman

WILLIAM P. ABENDROTH
CHAS. M. FULK
PHILANDER NORTON
P. C. PAQUETTE

JOHN FRITZ MEDAL PRESENTED TO ORVILLE WRIGHT

The presentation of the John Fritz Medal to Orville Wright took place at a meeting in the Auditorium of the Engineering Societies Building, May 7th, 1920. Mr. Charles F. Rand presided and, after calling the meeting to order, announced the award of the John Fritz medal to Mr. Orville Wright for his achievement in the development of the airplane. Mr. Rand explained the origin and establishment of the medal in 1902 in honor of John Fritz of Bethlehem, Pa., and read the list of distinguished men to whom this medal had been previously awarded.

The medal is awarded annually by a Board appointed by four National Engineering Societies,—the American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers and the American Institute of Electrical Engineers.

Mr. Rand introduced Major-General George O. Squire, who described Mr. Wright's early works in connection with the test and purchase of the first Wright airplane by the United States Government. Colonel Edward A. Deeds, the next speaker, described the early life of the Wright brothers and the many struggles and discouragements which they experienced before producing a practical airplane.

Prof. C. A. Adams then presented Mr. Wright with the medal and diploma, on which is inscribed the record of the award with the signatures of all the members of the Board of Award. Mr. Wright responded briefly, expressing his appreciation of the honor conferred upon him and acknowledging the help and inspiration he had received from many of his predecessors in aeronautics.

MEMORIAL MEETING FOR ANDREW CARNEGIE

On Sunday afternoon, April 25, at 3:30 p. m., a meeting was held in memory of the life and work of Andrew Carnegie at the Engineering Societies Building, 29 West Thirty-ninth Street, New York. The meeting was under the auspices of the Author's Club, the New York Public Library, the Oratorio Society, Saint Andrew's Society and the United Engineering Society. The meeting was opened by an invocation by the Rev. William Pierson Merrill.

Mr. J. Vipond Davies, Presiding Officer, after some introductory remarks read letters of tribute from Ex-president Taft, Viscount Morley, Viscount Brice and Sir Oliver Lodge, after which Dr. John H. Finley delivered an address, in which he told of many incidents in the life and work of Andrew Carnegie. Dr. Finley's address was followed by a selection, "Peace Hymn of the Republic", rendered by the Oratorio Society.

Mr. Elihu Root gave an address in which he traced the course of Mr. Carnegie's benefactions. The meeting concluded with the "Hallelujah Chorus", rendered by the Oratorio Society.

The memorial services were under the auspices of a Committee of Arrangements, which included Walter Damrosch, J. Vipond Davies, Cleveland H. Dodge, John Erskine, Alex. C. Humphreys, Rossiter Johnson, George F. Kunz, Lewis Cass Ledyard, Henry Moir, Charles F. Rand, Calvin W. Rice, Charles M. Schwab.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

AMERICAN DELEGATES ATTEND MEETING OF ADVISORY COMMITTEES IN BRUSSELS

Meetings of the Advisory Technical Committees of the International Electrotechnical Commission were held in Brussels March 27th to April 1st. The meetings were attended by delegates from eight national committees—Belgium, France, Great Britain, Holland, Italy, Spain, Switzerland, and the United States. There were about 40 delegates in all.

Although official decisions of the Commission are made only in plenary meetings, much of the work of the Commission is accomplished in the meetings of the Advisory Committees. Four of the Committees met at Brussels, namely: Rating, Definitions, Graphical Symbols, and Standard Voltages.

The meetings were attended by six American delegates—Messrs. C. O. Mailloux, C. E. Skinner, H. M. Hobart, A. H. Moore, L. W. Chubb, and P. G. Agnew. Dr. Mailloux is President both of the International Electrotechnical Commission and of the United States National Committee.

Rating. The Advisory Committee on Rating was presided over by Mr. Guido Semenza of Italy. The principal results of the meeting of this committee were the acceptance of:

1. The hot-spot principle as a basis of standardization. It was agreed, however, that the *working* rules should contain only

values of limiting observable temperature and temperature rise, and not the actual hot-spot values.

2. The classification of insulating materials. This classification is the same as the present A. I. E. E. rules with the addition of a new class, to be known as class "O", of unimpregnated cotton and similar materials.

3. The classification of methods of measurement, is the which same as that of the A. I. E. E. rules.

At the request of the American delegates the question of the terminal marking for transformers was deferred with the understanding that the American committee would submit a scheme sufficiently comprehensive to include all classes of apparatus and machinery.

Definitions. This committee held joint sessions with the committee on Symbols, under the presidency of Professor Janet of France. Definitions of about 60 terms were approved. These are terms which have been before the national committees for several years. There was considerable discussion as to advisability of attempting the preparation of a fairly complete International Electrotechnical vocabulary. Such vocabularies have been prepared by the national committees of France, Holland, and Italy. It was decided that these might serve as a basis of an international vocabulary, and a special committee was authorized for actively undertaking the work of its preparation. It is planned that this special committee shall hold its first meeting in Zurich.

Objection was received to the use of the word "gauss" as the unit of both magnetic force and magnetic induction. The question of the name for the unit of magnetic force was referred to the national committees.

A resolution was unanimously passed requesting the national committees to use their influence to prevent the formulation and introduction into use of electrotechnical terms which might ultimately present serious obstacles to international agreement.

Symbols. The Italian graphical symbols which had been formally submitted by the Italian National Committee at a previous meeting, were taken as a basis for discussion. The comprehensive list prepared by the British Engineering Standards Association, and Mr. Cheney's paper in the JOURNAL of the A. I. E. E., for February, 1920, which embodied the work of an A. I. E. E. sub-committee, were used as supplementary documents. Agreement was reached upon a list of about 100 symbols.

Standard Voltages. Owing to variety of circumstances, a great many voltages are now in use in Europe, and in the absence of standardization work, other voltages are being added. The European delegates felt strongly that immediate work should be done on two subjects—the standardization of voltages up to about 50,000, and the standardization of specifications for pin insulators. Some tentative proposals were formulated for the consideration of the various national committees. In informal conversations it was urged upon the American delegates that it would be very desirable for a comprehensive statement of American practise, accompanied by proposals, to be prepared and forwarded for the consideration of the other national committees.

As the meeting was not a plenary one, the actions of the advisory committees are not official decisions of the International Electrotechnical Commission. They are now before the national committees for study before official action is taken in a future plenary meeting.

The success of the meeting owes much to the very fine arrangements which were made by the Belgian committee, not only for the efficiency of the meeting but for the convenience and comfort of the visiting delegates. The President of the Belgian committee is Professor de Bast, and the Secretary is Mr. M. E. Uytborck. On Sunday, the delegates were conducted over the Yser battlefields by Capt. Leon Gerard, a member of the Belgian committee, and a great many of the devastated areas, including Courtrai, Nieuport, Dixmude and Ypres, were visited.

ENGINEERING SOCIETIES CALL NATIONAL ORGANIZATION CONFERENCE FOR JUNE 3-4, 1920

A call has been issued to the Engineering organizations of the United States for a conference on June 3rd and 4th, in Washington, D. C., for the consideration of the recommendations of the Joint Conference Committee of the Development Committees of the Founder Societies, relating to the formation of an affiliation of national and local engineering societies.

These plans call for the bringing into existence of a comprehensive organization or federation of the entire engineering profession; to place in the hands of a democratic body of engineers from existing engineering organizations of every kind all over the United States the authority and responsibility to speak for the engineering profession and to take united action on matters of common concern.

This movement is in harmony with a recommendation in the report of the Development Committee of the Institute, which was approved by the Board of Directors in August, 1919. The Board authorized the Development Committee to appoint delegates to a joint conference on this subject with the other Founder Societies. The Joint Committee submitted a report to the Board in October, 1919, which was published in the November PROCEEDINGS. In November the Board approved in principle the recommendations in this report and authorized the Institute's representatives to join with the conferees of such other societies as approved the report, in putting into effect the plan outlined.

The following has been adopted as a basis of representation at the Organizing Conference: Each national organization will be entitled to one delegate for 100 to 1000 members and an additional delegate for each additional 1000 members or major fraction thereof. Under this plan the Institute with a membership of over 11,000 would be entitled to eleven delegates.

NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

The Sixth National Exposition of Chemical Industries will be held in Grand Central Palace, New York, during the week September 20th to 25th inclusive. This will be the largest distinctly industrial exposition ever held, surpassing its own predecessors by one-third. It is to be divided into three special sections, one, the Electric Furnace Section, another the Fuel Economy Section, and the third a Materials Handling Section. The first will as its name implies be one of electric furnace exhibits; the fuel economy section will consist of exhibits of machinery and apparatus, furnaces, producers, stokers and all devices for the economic utilization or more efficient combustion of fuel. The possible exhaustion of our fuel reserves in the not far distant future and the present high cost of fuel makes this section one of much interest to all industrial plants. The Materials Handling Section will be a series of exhibits of machinery and equipment for the handling of material such as: conveying, transporting, elevating, included in this will be weighing, measuring and power transmission equipment. So important have these mechanical features become for all industrial plants due to the shortage and high-wage for man-power that an unusual interest is expected in this new Section.

The program for the exposition will have sessions on subjects the phases of which will be developed in the exhibits of these latter two sections. There will be sessions on chemical engineering for which an elaborate program is planned. Motion pictures which will have a keen interest for technical men will form part of the program, and there will be popular public addresses as well.

ARTHUR W. BERRESFORD

President Elect of A. I. E. E.

Mr. Arthur W. Berresford has been elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1920, as announced in the report of the annual meeting published elsewhere in this issue.

Mr. Berresford was graduated from the Brooklyn Polytechnic Institute, 1892, and from Cornell University, 1893. He was actively engaged in electrical engineering work with operating and manufacturing companies until 1900, when he became identified with the Engineering Department of the Cutler-Hammer Manufacturing Company, and has remained continuously with that company, of which he is now Vice-President and General Manager.

Mr. Berresford became an Associate of the Institute in 1894 and was transferred to the grade of Fellow in 1914. He has been active and enthusiastic in promoting the welfare of the Institute having served as a member of many important committees and as chairman of several. He was a Manager 1909-12 and a Vice-President 1912-14. Mr. Berresford is eminently qualified for the presidency by engineering experience, executive ability, and service to the Institute.

ARTHUR W. BERRESFORD
President Elect of A. I. E. E.

ENGINEERING FOUNDATION

SEEKING LARGE ENDOWMENT

Based on the generous gifts and high purpose of Ambrose Swasey, Engineering Foundation has since 1915, maintained a liaison between engineers, as represented by the Founder and other societies, and scientific workers, as represented in National Research Council. Practical means for cooperation in research have been set up so that engineers in the numerous branches of the Profession may join with physicists, chemists, geologists, geographers, psychologists, doctors, biologists, educators and anthropologists, in the attack upon problems of common interest and in the exchange of knowledge.

Potential benefits for the whole Nation are very great, but these benefits cannot be gained without expenditure of effort and materials. Research workers must be supported. Equipment, materials, working places and traveling facilities must be provided. Since the benefits accrue to the professions, the industries and the public in general, support in large measure should come from general funds, such as those provided by endowments. Although engineers, like other professional men as a class, are not wealthy, some individual engineers have large means. Engineering foundation seeks to build up its endowment to dimensions worthy of the Profession. Engineers connected with industrial and financial organizations having great resources can aid by convincing proper officials of corporations that the continued prosperity of our industries depends upon continued progress of research. Since the commercial and industrial establishments of the country reap the larger proportions of the financial profits arising from scientific and technological work these establishments should contribute liberally to the support of research.

Scientists are more largely concerned in research in pure

science, the search for undiscovered knowledge for its own sake, the usefulness of which may not become apparent in some instances for many years. Between this most advanced line and the development of specific industrial devices or processes, lies the large field of research in applied science and the industries which especially concerns technologists. In this broad field there is scarcely an item of work in which the engineer in some branch of his practise is not directly concerned. Sooner or later the engineer uses all the results of research in science and the industries.

There are many problems relating to the materials and forces of engineering on which further knowledge is needed. Progress will be made approximately in proportion to the funds made available. But there are other kinds of problems which concern the engineer. No longer may one declare, as did Professor J. B. Johnson, a generation ago, that "Engineering differs from all other learned professions in this, that its learning has to do only with the inanimate world, the world of dead matter and force." Many acute social and economic questions of our day need the dispassionate, impartial, patient study of scientists and technologists. To these questions must now be applied the scientific method of collecting facts by thorough study, and the engineer's capacity for planning and performing, instead of ill-considered "reforms."

Engineering works, public, corporate and private, frequently involve studies of special problems or in themselves constitute full-sized experiments, which could be made to yield important data for general technical use. Sometimes the engineers in charge do not perceive the opportunity, not having been trained in research work. More often the possibilities are realized, but means, men and time are not available because of the urgency for completing the project with a minimum expenditure in the shortest practicable time.

Occasionally experimental work is undertaken in accordance with a well conceived plan as a necessary or desirable adjunct to the main operation. In such cases the exigencies of the main operation sooner or later interrupt the experimental work; or the men who have it in hand leave the force; or the information is gained, but never written up; or the statement is buried in some report of limited circulation; or greater familiarity with research methods and a broader conception of the problem could, with small additional expense, have secured much more valuable results and have made them more generally useful.

Again, many construction or manufacturing operations might be made to yield useful data of greater value than those obtained from small-scale laboratory experiments, if only trained observers with suitable instruments were provided. Often the expense would be slight. Sometimes for lack of trained observers occurrences of scientific significance pass unnoted.

The services described in the foregoing paragraphs, and many others, could be performed by Engineering Foundation, if adequate funds could be placed at its disposal. The Foundation does not plan to build laboratories and conduct research work directly but rather to stimulate coordinate and support research work in existing scientific and industrial laboratories cooperating, insofar as may prove advantageous, with the, National Research Council.

Mr. Charles F. Rand, of 71 Broadway, New York, Past-President of United Engineering Society, and of the American Institute of Mining and Metallurgical Engineers, was elected chairman of Engineering Foundation March 19, to succeed Dr. W. F. M. Goss, resigned. With the collaboration of Mr. Swasey, Mr. Rand is actively seeking additions to the endowment fund which will swell the total to at least a million dollars in the near future. Mr. Swasey's gifts amount to $300,000.

The office of Engineering Foundation is in Engineering Societies Building, 29 West 39th Street, New York. Further information may be had by addressing this office or Chairman. A booklet giving an account of the Engineering Foundation and its work will be mailed upon request.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

COMMITTEE ON COOPERATION WITH AMERICAN INSTITUTE OF ARCHITECTS

The Committee on Cooperation with the American Institute of Architects met in Washington on May 4. A general discussion on the bill for licensing engineers as submitted by the License Committee of Engineering Council was held. The similarity of the functions of engineers and architects was also discussed. It was the unanimous recommendation of the Committee that in their judgment it was desirable for the American Institute of Architects to become members of Engineering Council and that the members of the Committee belonging to the American Institute of Architects submit it to them for their consideration. It was further agreed that cooperation of architects and engineers was desirable in formulating basic laws involving the registration or licensing of architects and engineers.

The afternoon session was devoted to a discussion regarding the design and construction of certain bridges. The Committee also touched upon the subject of unionization of draftsmen, and it was unanimously agreed that Engineering Council should be requested to appoint a Committee to consider the desirability of the unionization of draftsmen and other subordinate employees.

PREPARATION OF LEGAL PAPERS BY ENGINEERS

The New York Court of Appeals recently handed down an opinion which seemed to restrict the drawing of legal documents to persons possessing the right to practise law. This raised question in the minds of some engineers as to whether engineers and architects could continue in New York State to prepare contracts and certain other legal or semi-legal documents as has been their practise hitherto. Such a request was referred by the American Society of Mechanical Engineers to Engineering Council. The letter below contains an answer by an eminent legal authority.

Law Offices of
PARKER & AARON
New York

April 15, 1920

Alfred D. Flinn, Esq., Secretary,
Engineering Council.

We have your inquiry of March 16th calling our attention to the decision recently rendered by the Court of Appeals, Judge Crane writing the opinion. The decision referred to is that of People vs. Alfani, 227 N. Y., p. 334. In that case there was evidence, as the chief Judge said, "consisting of defendant's

sign and repeated acts which permitted the trial court to find that the defendant held himself out to the public as being entitled to and did practise law." Defendant had a sign up advertising himself as a Notary Public and as a person drawing "all legal papers." The evidence showed that he did draw a bill of sale and chattel mortgage and advised as to the necessity of filing the mortgage in the County Clerk's Office and that he charged and received $4.00 therefor. When the client was leaving he inquired of the defendant, "In case I have any trouble of any kind and I need any legal advice, can I come back to you?" to which the defendant replied "Yes."

In People vs. Title Guarantee & Trust Co., 227 N. Y., p. 366, a similar question arose in the prosecution against the Title Guarantee & Trust Company for drawing deeds and similar instruments in connection with their business of insuring titles to real estate, and the court held that such action did not violate the statute. The Court says:

"We know that in cities constantly men engaged in the real estate business and banks have prepared for their customers such instruments without doubt or criticism.

The Legislature when it enacted not only section 280 of the Penal Law, which we have been considering, but also section 270 relating to the practise of law by an individual without being admitted and registered, was charged with the same knowledge of prevailing customs and practises with which we are chargeable. Its members knew, oftentimes doubtless by practical and personal observation and experience, that laymen throughout the state were rendering such services as are here involved. Not only by practise and custom but by inherent privilege they had the right to do this unless forbidden by statute, and if the legislature intended to prohibit a widespread practise and establish a new rule it was its duty to say so clearly and unmistakably in the statute relating to the practise of law and rendition of legal services by individuals. It did not say so and in my opinion there is not to be found in that section of the Penal Law any provision against the rendition of such services by an individual. We think the same idea is emphasized as in section 280 that an individual who is not admitted to practise must not assume the character of an attorney at law. He is forbidden to practise or appear 'as an attorney at law or as an attorney and counselor at law' or to make it a business to practise 'as an attorney at law or an attorney and counselor at law' or to hold himself out to the public as being entitled 'to practise law as aforesaid or in any other manner' or 'to assume to be an attorney or counselor at law'. But there is nothing which can fairly be regarded as indicating an intention to abolish an existing and widespread practise and to prevent a layman as such and without any simulation of or pretense to the character of an attorney from drawing a simple instrument as instructed by his customer and not involving or predicated upon any legal advice then given."

Engineers having special knowledge of the engineering work required and the professional skill enabling them to express it, are not precluded as an incident in the practise of their profession from preparing "contracts for engineering work as has been the common practise for years". By so doing they are not holding themselves out as practising law and are not practising law.

Very truly yours.

(signed) PARKER & AARON.

CURRENT ENGINEERING TOPICS

ARMY REORGANIZATION BILL

The Lenroot Amendment to strike out the section of the Army Reorganization Bill which provides a separate construction service was defeated in the Senate by a vote of 18 to 38. When the House was considering the Army Reorganization Bill it had first voted to maintain the Construction Division as a separate service and later reversed its vote by the very small margin of 168 to 158. This is the most vital thing in the Army Reorganization Bill from the civilian engineer's standpoint; and it is distinctly a compliment to the manner in which civilian engineers handled the construction service during the last emergency.

PROVISIONS OF ENGINEERING INTEREST IN LEGISLATIVE, EXECUTIVE AND JUDICIAL APPROPRIATION BILL

This bill is finally passed by Congress provides $60,000 for enforcing the wireless communication laws; $30,000 is provided for investigation and standardization of methods and instruments employed in radio communication. The work is to be done at the Bureau of Standards.

The sum of $25,000 was provided for the continuation of the present investigations on the production of optical glass; $25,000 is allowed for metallurgical research; $30,000 for testing chemicals, etc., and $10,000 for the development of color standards and color measurements.

The structual materials investigation which has been carried on at the Bureau of Standards is provided with an additional $125,000. This investigation pertains largely to cement. $25,000 was appropriated for investigation of fire resisting properties of building materials and conditions under which they may be most efficiently used.

For the further investigation of standards of practise and methods of measurement of public utilities, such as gas, electric light and power, water, telephone, central station heating, and electric railway service, there was appropriated $85,000.

Forty thousand dollars were authorized to be used in the standardization and testing of gages, screw-threads, and standards required in manufacturing. $15,000 additional is to be used for developments of methods of testing and standardizing machines, motors, tools, measuring instruments, and other apparatus and devices used in mechanical, hydraulic and aeronautic engineering.

CIVILIAN ENGINEERING TRAINING FOR ARMY AIR OFFICERS

Not more than twenty-five officers of the Army are to be detailed to pursue courses of aeronautical engineering at colleges and universities throughout the states that are fitted to give such instruction, according to the provisions of a bill which has just passed the Senate.

The bill authorizes the Secretary of War to detail these officers and to make choice of colleges and universities to which they are to be assigned.

U. S. CHAMBER OF COMMERCE ELECTS DIRECTORS

The Chamber of Commerce, U. S. A., at its annual meeting in Atlantic City, April 26 to 29, elected two engineers as Directors of the Chamber. Mr. Howard Elliott, Member, American Society of Civil Engineers; Chairman Board, Northern Pacific R. R., New York City. Mr. L. B. Stillwell, Past-President, American Institute of Consulting Engineers and of American Society of Electrical Engineers; Member, American Society of Civil Engineers; Consulting Engineer, New York City.

DR. C. O. MAILLOUX ELECTED HONORARY MEMBER OF THE FRENCH SOCIETY OF ELECTRICIANS

Shortly after the election of Dr. C. O. Mailloux (Past President of the A. I. E. E.) to the Presidency of the International Electrotechnical Commission, last October, he was proposed, by Prof. Blondel, and other prominent French electrical men, for honorary membership in the Societe Francaise des Electriciens. Dr. Mailloux had been advised unofficially of this election, but

had not received the official announcement thereof, which came during his absence abroad in a letter from the President of the Society informing him that he had been elected unanimously at a special general meeting held December 22, 1919.

The official *Journal* (Bulletin) of the Society for December, 1919 (No. 84), the publication of which was delayed several months by the printers' strike, and which has only recently arrived here, contains the official announcement of the election. The General Secretary of the Society, in moving the resolution, at the request of the President, recalled "the valued services of all kinds rendered to the cause of France by Dr. Mailloux who, by reason of his election to the Presidency of the International Electrotechnical Commission, was entitled to a place among the Honorary members of the Societe Francais des Electriciens." The vote was unanimous. Dr. Mailloux, while in Europe, received many congratulations upon this new and high honor.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

GRADUATE ENGINEER, for part time work in correspondence courses in Dynamo Electric Machinery. Practical operation experience necessary; power experience preferred to industrial. Teaching experience not required. Location New York City. Z-1291.

INSTRUCTION IN ELECTRICAL ENGINEERING. Duties beginning Sept. 1st, in New England College mainly instruction in Electrical Engineering laboratory. Graduate of one or two years experience desired.

ENGINEER for research and investigation on cable insulations. Must be able to conduct investigation on own initiative and report progress of company. Location Hastings, N. Y. Z-1227.

ELECTRICAL OR MECHANICAL ENGINEERS, technically trained, with selling experience on electrical or power plant installations to go to Columbia or Venezuela. Prefer men who have been through the General Electric Company's test. Age between 25 and 35. Z-1275.

ELECTRICAL ENGINEER experienced in small house lighting systems. Engineer experienced in control apparatus desirable. Location New York City. Z-1248.

GRADUATE ELECTRICAL ENGINEER for mining company in Mexico. Some electrical testing and construction experience essential and must be able to keep the present plant in working order. Spanish desirable but not essential. Location Mexico. Z-1249.

ELECTRICAL ENGINEER familiar with the theory and design of Chadburn, Cory, Evershed Ford, Sperry and Vickers systems of fire control instruments and ability to make necessary adjustments and check accuracy of completed installation also to give instructions as to care and use of such apparatus. For further information see U. S. Civil Service or book on file in this office. Z-1254.

ILLUMINATING ENGINEER to prepare correspondence course in Electric Lighting and also to correct papers. Teaching experience desirable, but the ability to explain in writing is essential. Must be located near New York City. Z-1235.

ASSISTANT ENGINEER in general municipal practise, but particularly waterworks, electric light and sewer construction. Prefer man between the ages of 28 and 35 possessing good health, good address, and a reasonably pleasing personality. He must be of unquestioned integrity and veracity, energetic and competent. Location Tennessee. Z-1259.

RESIDENT ENGINEERS for general municipal practise, but particulary water works, electric light and sewer construction. Prefer man between the ages of 28-35 possessing good health, good address, and a reasonably pleasing personality. He must be of unquestioned integrity and veracity, energetic and competent. Location Tennessee. Z-1240.

GRADUATE MECHANICAL AND ELECTRICAL ENGINEER experience in car shop work. Competent to keep in first class condition of maintenance sub-surface-contract, electric, street railway cars, and to develop a repair shop for that work, selecting and placing the proper tools and take charge of such operations when effected. Location New York City. Z-1211.

INSTRUCTOR for technical school in electrical laboratory and class room work. Duties will include responsibility for an elementary electrical course, and assistance in a more advanced course. Must be engineering school graduate with few years practical experience. Previous teaching experience desirable. Apply by letter stating age, education and experience and enclose recent photograph if available. Location Brooklyn, New York. Z-1214.

GRADUATE ELECTRICAL ENGINEER experienced in electrical machinery for export office. Spanish desirable. Location New York City. Z-1175.

ELECTRICAL AND MECHANICAL ENGINEER for 3000 H. P. hydro electric plant in Bolivia. Must be able to improve, efficient and take charge of plant. Z-1150.

HEATING AND VENTILATION DRAFTSMAN in connection with construction work. Position involves board work on heating and ventilating systems exclusively. We prefer a graduate engineer who has had three or four years of practical experience in this work. Salary is not fixed but is commensurate with the man's ability. Permanent position with excellent opportunity for advancement. Location Ohio. Z-1133.

YOUNG ELECTRICAL DRAFTSMAN for illumination work. A man who has had two years technical training and who is able and willing to do drafting may be able to fill our requirements in this case. Permanent position with excellent opportunities for advancement. Location Ohio. Z-1134.

DRAFTSMAN to lay out wiring for lighting and power work for various types of buildings. Must have had experience with some electrical contractors. State experience, age and salary desired. Location New York City. Z-1138.

ELECTRICAL ENGINEER for drafting and layout work also work in field. This is for railroad company in New York City. Z-1142.

YOUNG MAN for engineering research and manufacturing departments of concern making grafonolas, records and dictaphone. Technical education essential with from one to eight years experience. Only men of caliber and ability considered. Location Connecticut. Z-1121.

ELECTRICAL ENGINEER for research work on obtaining Helium from natural gas, also draftsman for same work. Location Texas. Z-1125.

INSTRUCTORS. An examination will be held in Sampson Hall U. S. Naval Academy, Annapolis, Maryland, beginning at 9:00 a. m. Tuesday, June 15, 1920, for the selection of five instructors in the Department of Electrical Engineering and Physics. A bill now before Congress increases these salaries about 30%. Candidates must demonstrate a thorough knowledge of one of the subjects of Physics, Chemistry or Electrical engineering, and a sufficient grounding in the others to enable them to teach if necessary. Blank forms forwarded on request. Location Maryland. Z-1064.

TRAFFIC ENGINEERS for fruit cargo vessels. Technical training essential and practical experience and some knowledge of refrigeration fans, motors, etc., required. Work will be on board steamers which carry refrigerated banana cargoes and possibly some time spent in port occasionally. Regular schedule of boats gives about five days in New York each four weeks. Work will consist of investigation of transportation problems and supervision of care of fruit, etc., and should be pleasant as most of boats are large, well fitted carry good class of passengers. Z-1112.

EXECUTIVE ENGINEER to erect and operate an electric plant for the manufacture of ferro-vanadium. Actual experience of one of the existing plants now making this product essential. Must be entirely familiar with the technique of the electric process and be able to tell whether an ore is suitable for such process. Location either New Jersey or Colorado. Z-1117.

ELECTRICAL ENGINEER (A) with 3 or more years teaching experience desiring to make changes to electrical machine design work wanted to take up interesting line of alternating current development. Splendid opportunity for man of ability and energy to make permanent connection. ENGINEER (B) with technical training, experienced in design of alternating current motors to take up development of adjustable and varying speed alternating current equipment. Permanent position with good opportunities for growth. TECHNICALLY TRAINED ENGINEER (C) with railway operating experience, desiring to make change to design work, wanted for development work connected with railway electrification. Permanent position for man of ability. Z-1093 A-B-C.

ASSISTANT SUPERINTENDENT OF ELECTRICAL DEPARTMENT. Technical graduate with some experience in electrical construction works. Duties would consist of drafting, office work and outside construction supervision. Must also be able to assist in systematizing department employing about 30 men. Z-1079.

LUBRICATION ENGINEER for the Philippines; must be able to speak Spanish fluently and must be experienced as there is no time for instruction. Salary $3000 and traveling expenses. Location, Philippines. Z-901.

LABORATORY INSTRUCTOR IN ELECTRICAL ENGINEERING at a midwestern State College. Position open September 1st 1920. Z-1292.

MEN AVAILABLE

ELECTRICAL ENGINEER, technical education with 16 years experience in installations of all standard power house and substation equipments up to 110,000 volts. Have also electric furnace operation experience and maintenance of power house and substation equipment rebuilding of generators and transformers. Married, 36 years, salary depends on location. E-2199.

TELEGRAPH ENGINEER, small electrical apparatus all kinds. Twenty years experience including four years abroad. Sales and foreign trade understood, also foreign telegraph systems. Desire position anywhere abroad on salary, or will accept commission if good proposition. E-2200.

RAILWAY ENGINEER, technical graduate, eight years of vigorous experience in this branch with large manufacturing company. Steam road electrification work preferred although will consider any engineering work pertaining to electric traction. Married Age 32. E-2201.

EXECUTIVE, GRADUATE ELECTRICAL ENGINEER of broad mechanical and electrical experience with well known corporations, in production and design of electrical applicances, and in the steel and elevator industries. Factory manager familiar with modern production methods. Now engineer executive with large company. Location New York. Salary $6000. E-2202.

ELECTRICAL ENGINEER with twenty years varied experience in electrical field, viz. construction, estimating, contracting, jobbers salesman etc. including several years as teacher of electrical applications in a nationally known vocational school. Will consider position in any of the general lines indicated above. Last years salary bonus and commissions over $5000. E-2203.

ELECTRICAL MECHANICAL ENGINEER, Age 33, Three and half years technical training, nine years practical engineering experience, in design, construction, operation and maintenance of large electric powerplants, high tension systems, transformer, switching and rotary converter sub-stations, familiar with sugar house electrification and industrial plant installations, efficient with large steam turbine, reciprocating engine and internal combustion engine driven power plants, erection and installations of boilers and condensing systems. Good organizer, speaks Spanish fluently. Familiar with all kinds of Labor found in Latin Americas. Salary $5000 per year to start, traveling expenses, will go to any part of the world. Available after May 15th, Address Engineer, Apartado 2593, Havana, Cuba. E-2204

ELECTRICAL ENGINEER; age 27, married, technical graduate Three years teaching experience in electrical engineering, one year in Physics. Now in latter position. Considerable knowledge of radio. Desires position in teaching or commercial work. Available June 15th. E-2205.

GRADUATE ELECTRICAL ENGINEER B. S. Degree, wishes position as Assistant to engineer. Have had a varied experienced in testing and maintenance electrical machinery and equipment. Location preferably in east, but not essential. Minimum Salary 1800. E-2206.

GRADUATE ELECTRICAL ENGINEER (1911) married, age 31, desires position of greater responsibility in consulting and sales work. Has had factory and office experience also erection repair and executive experience with Westinghouse and General Electric. Capable of handling construction erection work also sales engineer. Location middle west. Salary $3300. Available soon. E-2207.

INDUSTRIAL ENGINEER, technical graduate, Assoc. Member A. I. E. E. Assoc. Member A. S. C. E. Twelve years practical experience, surveys, designs, and construction supervision, millbuildings and equipment, structural steel, reinforced concrete designs and details, plant inventory, valuations, and inspection of construction materials, recently established in private practice at 50 Bromfield street, Boston Mass. Engineering service available on hourly basis. E-2208.

MECHANICAL & ELECTRICAL ENGINEER, college graduate, twenty years varied experiences, electrical mechanical, steam and selling, public service lighting and power, telephone and industrial companies in field and office, design, construction, maintenance, operation; good manager. Age 45; Available on reasonable notice. E-2209.

ELECTRICAL AND HYDRAULIC ENGINEER, twenty years experience as executive in design, construction, maintenance, and operation of large hydroelectric plant of 200,000 h. p. capacity. Experience includes heavy overhead and underground transmission and distribution systems. Has had much experience in power measurement and in preparing power contracts. Is ready to undertake general supervision of electrical development work of any size or act as technical adviser to investment syndicate. Reason for seeking new connection: merger. E-2210.

RESEARCH ENGINEER, graduate E. E. experienced in research and development of electrical appliances thoroughly familiar with patents and patent law, about to be registered as patent attorney, can handle laboratory of small concern, or assist in management of large one, available 30 days. Salary $2000. E-2211.

ELECTRICAL ENGINEER; age 30; 1916 Univ. graduate; 2 years Westinghouse test, trouble, and construction work. Considerable construction and layout experience before and after University work. Experienced teacher. Desires position as electrical engineer in power, electric railway or industrial service. Location preferred. Middle West. E-2212.

ELECTRICAL SUPERINTENDENT, graduate E. E., seven years industrial engineering, maintenance and construction; four years experience in manufacture and testing of wires and cables, desires to connect with a concern who can appreciate results. Correspondence and interviews solicited. H. Murray, 29 Gage Ave. So. Hamilton. Ontario, Canada. E-2213.

ELECTRICAL CONSTRUCTION ENGINEER or Chief Electrician for large plant. Seven years experience in installations of electrical machinery, repairs and design. Technical and Practical education. Age 25, Location anywhere. Available June 15. E-2214.

ELECTRICAL ENGINEER, thirty three, technical graduate, fourteen years electrical and mechanical design and construction; experienced in industrial plants, power houses and substation desires position of responsibility, with consulting or contracting engineers. Salary $3600. E-2215.

Electrical and Mechanical 18 years practical training technical education several years in charge of men, good on production and systematic. Wishes position as Superintendent of electrical department Works Engineer or Safety Engineer. What have you. Age 34, Married. Salary $2700. E-2216.

Plant or Works Engineer for large concerns to assume supervision of mechanics, draftsmen, electricians and general plant maintenance and construction, also generation and distribution of power heat and air. E-2217.

Power Sales Engineer—Graduate electrical engineer with five years experience in industrial power work, both with industrial concerns and public utilities. Desires permanent connection with an aggressive new business department of a public utility. E-2218.

Stenographers and Typists experienced, for part time work, afternoons, evenings, or Saturday all day. Work done at at home also. 40 Irving Place. Telephone Stuyvesant 5524.

Engineer, experienced in steam electric power and electric railway work; expert research man, especially in combustion and other technical investigations. Age 40, married, E.E. and M. S. Salary asked $4000. Permanent Position desired. E-2219.

Technical Electrical Graduate, Age 30, Married; 4 years power experience, desires a position with an Electrical establishment where there are good opportunities for advancement in the engineering field. Available on 30 days notice. E-2220.

Electrical Engineering Graduate, 1919; B.S. Age 23, Single desires position in engineering department of concern manufacturing electrical machinery or power supply company. Two years testing experience on D. C. Machinery. Salary $1500. E-2221.

Associate Professorship in Electrical and Telephone Engineering desired. Technical graduate, M. E. Six years combined teaching and consulting experience. Three years in Plant and Engineering Departments of Bell Telephone Company; two years in Electrical Distribution and Power Plant work; one and a half years training in Research work; will consider commercial position also. E-2222.

Foreman of Construction, 18 years experience in line construction of all classes conduit cable and motor installations, meters, etc. Married, 35 years old. E-2223.

ADDRESSES WANTED

A list of members whose mail has been returned by the Postal authorities, is given below, together with the addresses as they now appear, on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Arthur J. Hall, 634 East End Avenue, Pittsburgh, Pa.
2.—Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.
3.—Lieut. W. J. Strieby, 34 Simpson Road, Ardmore, Pa.
4.—Charles P. Wood, Metuchen, N. J.

PERSONAL

Ludwig Hommel will continue to be in charge of the Pittsburgh office of the Wagner Electric Manufacturing Company, which has been moved to 530–534 Fernando Street.

Frederick G. Cottrell, Chief Metallurgist, Bureau of Mines, was nominated May 5 by President Wilson to be Director of Bureau, succeeding Dr. Van H. Manning, whose resignation will take effect June 1.

J. G. Carroll, chairman of the Pittsburg Section of the Institute, has left the service of the Westinghouse Electric & Manufacturing Company, at East Pittsburgh, and on May 1 became chief engineer of the Walker Vehicle Company, Chicago.

C. B. Daniels, Secretary of the Colorado Society of Engineers, announces the opening of a new office in the Cooper Building, Denver, Colo. Attention is invited to the free engineering employment service in cooperation with the U. S. Government free employment bureau, the Engineering Societies employment bureau, the Colorado free employment office, and other technical and welfare organizations.

Walter A. Hall, chairman of the Sections Committee of the Institute, has left the service of the General Electric Company, at West Lynn, and on April 15 became Vice-president and general manager of the Murray & Tregurtha Corporation, Atlantic, Mass., manufacturers of marine engines. This company, originating in 1889, has recently reorganized and is extending its activity in both marine and commercial fields.

W. S. Finlay, Jr., has resigned as Superintendent of Motive Power of the Interborough Rapid Transit Company to accept the position of a vice-president of the American Water Works & Electric Company. Mr. Finlay's early work in the I. R. T. Co. was identified with the construction of the 59th Street Power Station. In 1909 he left the Company, but returned in 1915 to take charge of the installation of turbines and auxiliary mechanical equipment necessitated by the extensions to the subway and elevated systems; and upon the death of Mr. H. G. Stott was appointed his successor as Superintendent of Motive Power.

Mr. Ira Cushing, formerly consulting engineer with The General Electric Company, has taken a position as electrical engineering salesman with Mr. James C. Barr, Manufacturers' Agent, 84 State St., Boston, Mass. specializing in the products of the Electrical Engineers Equipment Company of Chicago. and the Locke Insulator Corporation of Victor, N. Y., for which Mr. Barr is district representative in New England. Mr. Cushing entered the employ of The General Electric Company at Schenectady in December, 1901, and in 1906 he was transferred to the Boston Office of the company. He served for several years as Secretary-Treasurer of the Boston Section of the A. I. E. E. and in 1918 he was elected Chairman of the Section.

OBITUARY

John Bogart, civil engineer, died of pneumonia on April 26, 1920, at his home, 640 Madison Ave., New York, after an illness of eleven days. Mr. Bogart, a descendent of a Dutch family which settled in Albany in 1639, was associated during his early career with the development of Central Park. During the Civil War he worked on the fortification of Fort Monroe and other points. Subsequently he became chief engineer of the Park Department of New York, New York State engineer, constructing engineer of the Washington Bridge, New York, and chief engineer of the Rapid Transit Commission. Mr. Bogart was one of the foster fathers of the Institute, as it was during his term as secretary of the A. S. C. E. back in the pioneer days of Institute history, 1885 to 1887, that the Institute was granted permission to use the rooms of the A. S. C. E. on Twenty-third Street as a meeting place and home.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (APRIL 1-30, 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AIRCRAFT YEAR BOOK

Issued by Manufacturers Aircraft Association, Inc. 1920. Publ. by Doubleday, Page and Company, N. Y., illus., cloth, 9 x 6, 333 pp. $2.

The first issue of this annual review of the industry appeared in 1919. The present issue, the second of the series, reviews the progress up to date in various fields of aeronautical activity. Aircraft in commerce and in warfare, technical developments between 1914 and 1919, and cross country flying are discussed, and a detailed story of the recent achievements of the firms composing the Association is given. The book also contains the text of the convention relating to international air navigation, the report of the American Aviation Commission, a chronology of the events of 1919 and appendices giving information on governmental activities.

THE ALDRICH MARINE COMPANY.

N. Y., Aldrich Publishing Co., 1920. 246 pp., 8 x 4 in., flexible cloth, $5.

The third edition of this useful directory contains the list of concerns which build and repair vessels in the United States, and also of steamship, steamboat and other vessel owners operating ships under the American flag. The lists are divided geographically, the main sections covering the Atlantic Coast, the Pacific Coast, the Great Lakes and the Mississippi Valley. The shipbuilders' list comprises over 400 shipbuilding or repair yards and about 400 drydocks and marine railways. Particulars of Government-owned or controlled ships are not included. The volume is thoroughly indexed.

COURS DE MECANIQUE RATIONNELLE avec de Nombreuses Applications al'Usage des Ingénieurs—Cinématique—Statique—Dynamique.

By L. Legrand. 1920, Paris and Liége, ch. Beranger, 364 figures, 618 pp., cloth, 10 x 6 in., 48 fr.

The author of this textbook believes that there is need for a work which will present the subject in strictly scientific manner, but which will draw its illustrations from the realm of industrial mechanics, rather than from celestial mechanics, as is usually done in theoretical treatises, and presents the present book for this purpose. He has attempted to supply a complete course in which an engineer will find the theory illustrated by problems which arise in the practise of applied mechanics in various industries.

ECONOMIC DEMOCRACY.

By C. H. Douglas. N. Y., Harcourt, Brace and Howe, 1920, 5 x 8, 140 pp., cloth, $1.60.

This book, based on the cost of investigations of the author while assistant superintendent of the Royal Aircraft Factory of England, and written for the most part under the pressure of war conditions, is an attempt to disentangle from a mass of superficial features such as profiteering and alleged scarcity of commodities, a sufficient portion of the skeleton of the structure we call Society as will serve to suggest sound reasons for the decay with which it is now attacked, and afterwards to indicate the probable direction of sound and vital reconstruction. Democracy, the author believes to be not so much a matter of elective administration as of distributed economic power, the attainment of which is a question of the establishment of the just price and the control of the policy of industry through the mechanism of the credit system.

ELEMENTS OF STEAM AND GAS POWER ENGINEERING.

By Andrew A. Potter and James P. Calderwood. 1st edit. N. Y. and Lond., McGraw-Hill Book Company, 1920, 8 x 5, cloth, 297 pp., illus. $2.50.

The object of this treatise is to provide a clear, concrete statement of the principles underlying the construction and operation of steam and gas power equipment, suited to familiarize students of engineering with power plant equipment before they take up the study of thermodynamics and design, and to those responsible for the operation of power plants.

GEOLOGY OF THE MID-CONTINENT OILFIELDS.

By T. O. Bosworth. N. Y., The Macmillan Co., 1920. 314 pp. illus., plates, charts, maps, 9 x 6 in., cloth, $3.

Contents: Introduction and Bibliography. Geographical and Geological Situation of the Mid Continent Oil Region. History of the Development of the Mid Continent Oil Region. Geological Structure of the Mid Continent Oilfield Region. Geological History of the Oil Bearing Deposits. Stratigraphy and the Oilfields. The Oil Accumulations and their Relation to Geological Structure. Character of the Oil. The Natural Gas. Production of Gasoline from Natural Gas. Salinity of Oilfield Waters. Some General Conclusions.

The present interest in the search for oil makes this book on the greatest of the world's developed oil territories particularly timely. The fields included in this region have not heretofore been regularly grouped together as a whole in oil literature but have been scattered under different titles according to location. The author has endeavored to deal with the Mid Continent Oil Region as a well defined unit with a natural geological boundary, and to that end has set forth and reviewed the facts which he has drawn from many sources, especially the United States and the State Geological Surveys.

HANDBOOK OF ORE DRESSING—Equipment and Practise.

By A. W. Allen. 1st edit., N. Y. and Lond., McGraw-Hill Book Co., 1920. 166 fig. and tables, 240 pp., flexible cloth, 7 x 5 in., $3.

This is an attempt to supply a handy, practical vade-mecum for millmen and engineers which will cover the various stages in the mechanical handling and preparation of an ore for metallurgical treatment. The volume includes a brief bibliography and is of convenient size for the pocket.

HOW TO MAKE AND USE GRAPHIC CHARTS.

By Allan C. Haskell, with an introduction by Richard T. Dana. 1st edit., N. Y., Codex Book Co., 1919. 540 pp., diagrams, 6 x 9, cloth, $5.

The object of this book is to call attention to the many functions which graphic methods can accomplish and to indicate the suitability of the various methods of charting for various purposes. After describing the theory and construction of the various types of charts, the author gives many examples of charts used to aid in organization and management, in analyzing costs and operating characteristics, in recording tests, in predicting trends and tendencies, in computing, designing and estimating. Bibliographies are given with most of the chapters.

OPPORTUNITIES IN ENGINEERING.

By Charles M. Horton. N. Y. and Lond., Harper and Brothers. 90pp., 8 x 5 in., paper. $1.

The tremendous power which engineers wield in world affairs has inspired the author to set forth in this book the opportunities for constructive work which lie before the men who selects engineering as his profession. He also describes the type which, being best fitted for the work, is most likely to succeed and gives some hints for the guidance of the student who is choosing his vocation, as well as some examples of what has been done by those already in the work.

PROSPECTOR'S FIELD-BOOK AND GUIDE.

In the Search for and the Easy Determination of Ores and Other Useful Minerals. By H. S. Osborn. 9th edition thoroughly revised and enlarged by M. W. von Bernewitz. N. Y., Henry Carey Baird & Co., Inc., 1920. 364 pp., illus., tables, 7 x 5 in., flexible cloth, $3.

Since 1910, when the eighth edition of the Guide was published, conditions and methods in the mining field have changed, necessitating the addition of much new material in order to bring the work up to date. Lists of suitable outfits, new field tests, notes on sampling, an explanation of the unit system of selling ores and an entirely new chapter on the alloy minerals are included in this revision, and the principal characteristics of certain ore deposits in various parts of the world are discussed. The book also contains a glossary of mining and mineralogical terms and an appendix of useful tables.

RETAINING WALLS. Their design and Construction.

By George Paaswell. 1st edit. N. Y., and Lond., McGraw-Hill Book Co., 1920, diagrams and illus., 275 pp., 9 x 6, cloth, $4.

This work differs from the usual treatise on the subject by being essentially a text on the design and construction of retaining walls, rather than an analytic study of the action of the retained earth masses. The failures of the walls are usually not due to weaknesses in the theory of pressures, but to faulty design and construction, in the author's opinion, and it is to these questions he directs his attention.

TRANSIENT ELECTRIC PHENOMENA AND OSCILLATIONS, THEORY AND CALCULATION OF.

By Charles Proteus Steinmetz. 3rd edit., revised and enlarged, N. Y. and Lond., McGraw-Hill Book Company, Inc., 1920. 9 x 6, cloth, 696 pp. $6.

This volume, which is to some extent a continuation of the author's Theory and Calculation of Alternating Current Phenomena, deals with the transient phenomena of the readjustment of stored electrical energy which is necessitated by a change in circuit conditions. The present edition has undergone extensive revision and expansion, and has practically been rewritten. A new section, entitled "Variation of circuit constants", has been added. The method of symbolic representation has been changed from the time diagram to the crank diagram.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Boston.—May 4, 1920, Engineers Club. Report from different committees and election of officers as follows: Chairman, W. I. Middleton; Vice-Chairman, L. W. Abbott; Secretary-Treasurer, Ira Cushing. Subject: "Notes on Electric Power Conditions in New England and on the Pacific Coast During the War." Speaker: George F. Sever. Attendance 60.

Chicago.—April 26, 1920, Auditorium, Western Society of Engineers. Paper: "The Principle of Electric Precipitation and Its Application to Cement Kiln Gases." Speaker: Mr. John H. Lendi, Electrical Engineer of the Universal Portland Cement Company. The talk was illustrated with lantern slides which showed the latest development of the process as applied to cement plants. Attendance 103.

Cleveland.—April 20, 1920, Hotel Statler. Subject: "The Sperry Gyroscope". Speaker: Mr. Robert B. Lea, Engineer Marine Department, The Sperry Gyroscope Company, Brooklyn, N. Y. Attendance 162.

Denver.—April 24, 1920, Kenmark Hotel. Joint meeting of the Colorado Scientific Society, Denver Section A.I.E.E., and the Teknik Club of Denver. Paper: "Radio Telephony." Speaker: Mr. Harry R. Kylie, U. S. Forest Service. The paper was illustrated by diagrams and radio telephone apparatus. Attendance 95.

Indianapolis-Lafayette.—April 16, 1920, Chamber of Commerce. Subject: "Central Station Rates as Affected by Load Factor and Power Factor." Speaker: Professor C. Francis Harding, Purdue University. Attendance 55.

Ithaca.—April 12, 1920, Sibley Auditorium, Cornell University. Joint meeting with Cornell Branch A. S. M. E. Subject: "Industrial Relations." Speaker: Mr. C. F. Hirshfeld, Chief of Research Department, Detroit Edison Co. A social hour was held after the meeting. Attendance 500.

April 23, 1920, Franklin Hall, Cornell University. Subject: "High Tension Insulators." Speaker: Mr. A. O. Austin, Chief Engineer, Ohio Insulator Co. Attendance 40.

Madison.—May 5, 1920, Engineering Building, University of Wisconsin. Subject: "Abstractive and Selective Properties of Radio Circuits." Speaker: Professor Edward Bennett, University of Wisconsin. Professor Bennett gave a brief discussion of some of the requirements of radio circuits to obtain least interference, and to obtain the greatest amount of power from the particular sending station one wished to listen in on. Attendance 25.

Philadelphia.—May 10, 1920 Engineers' Club. A dinner preceded the meeting. Subject: "Professional and Financial Aspect of Electrical Engineering." Speakers: C. W. Plass "Financial Possibilities of the Electrical Engineer," A. W. Hastings and J. W. Anderson "A Comparison of Engineering with other Professions;" F. G. Macarow "Americanization in Industry;" W. H. J. McIntyre "The Value of an Apprenticeship Course to the Apprentice and to the Employer." Attendance at meeting 126.

Pittsfield.—April 15, 1920, Park Club. Subject: "Theory of Vacuum Tubes." Speaker: Professor J. H. Morecroft, New York, N. Y. Attendance 105.

May 7, 1920, Park Club. Subject: "Motor Application in the Large Steel Industries." Speaker: Mr. M. A. Whiting, General Electric Company, Schenectady, N. Y. Attendance 36.

Portland.—April 13, 1920, University Club. Subject: "Preliminary Reconnaissance of the Skagit River Power Project

of the city of Seattle." Speaker: Mr. C. F. Uhden, Attendance 60.

St. Louis.—April 28, 1920, Union Electric Assembly. This was a social meeting, opened with the presentation of the five reel picture "The Cody Trail" and followed by another film "Through the Canadian Rockies." Dancing followed the showing of the pictures, and a buffet luncheon was served. Attendance 160.

Schenectady.—April 16, 1920, Edison Club Hall. Subject: "The Transmission of Telephone Currents." Speaker: Mr. O. B. Blackwell, A. T. & T. Co., New York. Mr. Blackwell illustrated his talk by means of lantern slides. Attendance 120.

April 21, 1920, Edison Club Hall. Subject: "Self-Interest in Electrical Development." Speaker: Mr. A. Emory Wishon, President of the Pacific Coast Section of the N. E. L. A. Attendance 73.

Seattle.—April 20, 1920, Arctic Club Assembly. Business meeting followed by presentation of three papers by men from the Seattle Municipal Light and Power System as follows: Mr. F. R. Nicholas "New Features of the Cedar Falls Pipe Line;" Mr. W. J. McKeen "New Features of Power House Design;" Mr. Glen H. Smith "A New Plan of Distribution" which has been adopted by the department. All the papers were illustrated with lantern slides. Attendance 95.

Toronto.—April 9, 1920, Engineers' Club. Paper: "Protection of Power Circuits under Short-Circuit Conditions." Speaker Mr. I. W. Gross. Attendance 87.

April 23, 1920, Engineers' Club. Annual Meeting. Annual report of the Chairman was read and adopted. Election of officers as follows: Chairman, Frank R. Ewart; Secretary, Perry A. Borden; Executive, O. V. Anderson, L. B. Chubbuck, W. P. Dobson, S. E. M. Henderson, Geo. D. Leacock and Walter F. Wright. The meeting was followed by an informal dinner to President Calvert Townley. Attendance 47.

Washington.—April 13, 1920, Cosmos Club. Illustrated address on "Design of a Super-power Station" by Mr. Harold Goodwin, Jr. Attendance 105.

May 11, 1920, Cosmos Club. Election of officers as follows: Chairman, Milton M. Flanders; Secretary, Ernest T. Walker. After the business meeting a moving picture was shown "Electrification of the Butte, Anaconda and Pacific Railroad." Attendance 40.

PAST BRANCH MEETINGS

University of Arkansas.—April 13, 1920, Engineering Hall. Subjects: "Daylight Saving" by Jack Thompson; "Carbon Arcs for Searchlights" by George Moore; "Effect of Ranges on Distribution Layouts" by Loy Barton; "Current Events" by Max Ware. Attendance 21.

Armour Institute of Technology.—April 20, 1920, Armour Lecture Room. Illustrated lecture accompanied by lantern slides. Subject: "Electricity the Wonder Worker" by Chairman Seyferlich and Secretary Stevers. Attendance 36.

Brooklyn Polytechnic Institute.—April 16, 1920, Potts Lecture Room. Students Paper by Mr. T. M. Feder (class 1920) on "Principles of Design of H. T. Insulators." Also Mr. Elmer J. Goodale, of the New York and Queens Electric Light & Power Co., on "Protective Relays, Design and Application." Attendance 25.

April 30, 1920, Potts Lecture Room. Subject: "Vacuum Tubes". Speaker: Mr. H. J. Van der Bijl, Research Physicist, Western Electric Co. Refreshments were served after the meeting. Attendance 58.

Carnegie Institute of Technology.—April 29, 1920, Machinery Hall. Paper: "The Development of Electric Controllers." Speaker: Mr. H. D. James, Control Division, W. E. & M. Co. The paper was illustrated with a large number of slides. Attendance 40.

University of Cincinnati.—April 20, 1920, Assembly Room. Business meeting. Attendance 66.

April 27, 1920, Assembly Room. Two student papers were presented as follows: "Some Control Circuits as Used at the American Rolling Mill Co.," by Paul H. Felton '20, and "An Electrical Method of Determining the Amount of River Water in Turbine Condensate at the Union Gas & Elec. Co." by T. R. Watts '22. Attendance 69.

May 4, 1920, Engineering Building. Subject: "Some Special Slide Rules gotten up for Valuation Work on the B. & O. R. R." Speaker: Mr. C. S. Meyer. Attendance 75.

May 11, 1920, Engineering Building. Subject: "Results of Tests on a Four Wheel Driven Tractor." Speaker: Mr. A. A. Van Pelt. Attendance 67.

Clarkson College of Technology.—April 26, 1920, Clarkson Chapel. Films were shown on Electrification of Railroads, followed by general discussion. Attendance 78.

Clemson Agricultural College.—April 6, 1920, E. E. Lecture Room. Subject: "Railway Signal Systems." Discussions by Messrs. Cullum and Bunch; "Life of Lamme" by A. G. Gower. "Current Events" by C. O. Durant. Attendance 49.

April 20, 1920 E. E. Lecture Room. Subject: "Rectification of Alternating Currents" by W. D. Banks and Professor S. R. Rhodes; "Lightning" by L. H. Childs; "Current Events" by W. W. Fowler. Attendance 33.

Drexel Institute.—April 29, 1920. Business meeting, followed by paper on "Voltage and Current Regulation on Automobile Generators" by Mr. C. E. Rorda, of Drexel Institute. Attendance 16.

Georgia School of Technology.—April 15, 1920, Physic Lecture Hall. Paper: "Lightning Arresters." Speaker: C. E. Bennett, of the Georgia Railway and Power Company. The paper was illustrated with slides and demonstrated by means of a miniature transmission line. Attendance 55.

May 13, 1920, Y. M. C. A. Auditorium. Subject: "The Hydroelectric Development at Tallulah Falls." Speaker: Mr. C. G. Adsit, of the Georgia Railway & Power Company. Slides and moving pictures were shown of the dams and reservoirs at Burton, Mathis, and Tallulah Falls. Attendance 110.

University of Maine.—April 6, 1920, Lord Hall. Business meeting. Attendance 28.

Michigan Agricultural College.—April 15, 1920. Paper: "Changing Insulators on Live and Dead High-Tension Lines." Speaker: Mr. H. J. Burton, of the Consumers Power Company. Attendance 43.

School of Engineering of Milwaukee.—April 23, 1920. Subject: "Elevator Controls." Speaker: Mr. Harrison P. Reed, Cutler Hammer Mfg. Co. Attendance 70.

North Carolina State College.—March 2, 1920, E. E. Class-Room. Professor McIntyre, of the Electrical Department, gave an interesting talk on the telephone organizations; Mr. E. P. Holmes of the H. L. Doherty Co., and an alumnus of the college, gave a talk on his work since he left school. Attendance 29.

March 9, 1920, E. E. Class-Room. Business meeting regarding electrical show. Attendance 27.

March 16, 1920, E. E. Class-Room. The program consisted of several extemporaneous speeches by various members of the class on humorous subjects. Attendance 23.

March 23, 1920, E. E. Class-Room. Meeting devoted to discussion and work on the electrical show. Attendance 20.

March 30, 1920, E. E. Class-Room. Meeting devoted to discussion and work on the electrical show, the date of which was set for April 10 and 12. Attendance 20.

April 10 and 12, 1920. Electrical show held by the Branch at Winston Hall. The show consisted mainly of exhibitions, demonstrations and stunts with the machinery and apparatus of the extensive laboratory of the electrical department. The attendance for both nights was large.

April 20, 1920, E. E. Class-Room. Business meeting and election of officers: President, D. A. Floyd; Vice President, E. E. Inscoe; Secretary-Treasurer, H. W. Allsbrook. Attendance 21.

University of Notre Dame.—March 14, 1920, Engineering Hall. Paper: "Engineering as a Profession." Speaker: W. J. Douglass. Attendance 22.

March 29, 1920 Engineering Hall. Following papers presented: "The Engineer as a Citizen" by J. G. Malone; "Report on Thesis" by R. G. Arends; "Outline of the Students Course at the Fort Wayne Branch of the General Electric Co." by W. J. Hockett, of the G. E. Co. Attendance 24.

April 23, 1920, Engineering Hall. Paper: "Essentials of Successful Engineering." Speaker: Mr. J. E. Kearns, of the G. E. Co. of Chicago. Attendance 35.

Ohio Northern University.—March 23, 1920, Lehr Auditorium. The following motion pictures were shown: "Telephone Inventors of today" and "Indies the Big Fence." Attendance 232.

April 14, 1920, Dukes Memorial. Subjects: "Electric Vehicles" by Paul Rice, and "An Auto-transformer Installation at Trenton, N. J." by F. Veverka. Attendance 22.

April 21, 1920. Dukes Memorial. Subjects: "Some New Applications of Electricity" by E. A. Erdman, and "Water Power" by D. M. Bockenek. Attendance 16.

April 28, 1920, Dukes Memorial. Subjects: "Steam vs. Electric Locomotives" by Professor J. A. Needy; "The Manufacture of China Ware" was discussed by Mr. Edward Salt. Attendance 27.

May 12, 1920, Dukes Memorial. The purpose of the meeting was to nominate candidates for the Branch officers for the coming year. Attendance 32.

May 13, 1920, K. of P. Hall. Election of officers as follows: Chairman, E. A. Erdman; Vice-Chairman, Paul Rice; Secretary, John W. Ulrey; Treasurer, F. Veverks. Following the election of officers the following program was given in an informal manner: Boxing and Wrestling Matches; Talks by members of the faculty present, smokes and eats; remarks by members of the senior class present. Attendance 48.

Ohio State University.—March 28, 1920. Business meeting. Attendance 37.

University of Oklahoma.—May 6, 1920, Engineering Building. Subject: "The Design and Construction of Transformers." Speaker: Professor E. R. Page. Attendance 29.

Oregon State Agricultural College.—April 15, 1920. Subject: "Power Rates and Distribution." Speaker: Mr. F. E. McKenna, of the Mountain States Power Company. After the speaker had finished the following motion pictures were shown: "King of the Rails" and the "Butte Anaconda and Pacific Railroad." Attendance 68.

April 28, 1920. Subject: "Testing a Hydroelectric Plant" Speaker: Mr. W. D. Proebstel, of the Portland Railway Light and Power Company. Attendance 110.

University of Pennsylvania.—May 3, 1920, Engineering Building. Election of officers as follows: Chairman, J. F. Haines; Vice-Chairman, Heidelbaugh; Secretary, N. R. Guilbert; Treasurer, Gallagher. Subject of the meeting: "The Development of the Storage Battery." Speaker: J. Jones. Attendance 21.

University of Pittsburgh.—April 13, 1920. Paper: "Electric Furnaces in the Steel Industry." Speaker: C. E. Mc Gann. The paper was illustrated with lantern slides. Attendance 32.

April 20, 1920. Paper: "Los Angeles Power Development." Speaker: W. J. Zehfuss. Attendance 25.

April 27, 1920. Paper: "Niagara Falls Electric Development vs. Scenic Development. Speaker: E. D. Rowbottom. Attendance 19.

May 4, 1920. Paper: "Mississippi River Power Development. Speaker: W. B. Jones. The paper was illustrated with slides. Attendance 27.

May 11, 1920. Paper: "The Design of a small Automatic Hydro-Electric Station." Speaker: W. F. Young. Attendance 27.

Stanford University.—April 14, 1920. Business meeting. Attendance 15.

University of Virginia.—May 6, 1920, Mechanical Laboratory. Election of officers as follows: Chairman, Clark Forrest; Secretary-Treasurer, James O'R. Coleman. Paper: "Railway Signaling." Mr. Charles Stephens, of the C. & O. R. R. Professor Rodman read the paper in the absence of Mr. Stephens. Attendance 22.

University of Washington.—April 13, 1920, Forestry Hall. Subjects: "Advantages of the G. E. test for Engineering Graduates," slides and two reels of moving pictures, W. M. Nelson, of the G. E. Company; "The Status of the College Graduate in the Mind of the Professional Electrical Engineer," S. C. Lindsay, P. S. P. & L. Co. Attendance 44.

Yale University.—May 6, 1920, Dunham Laboratory of E. E. Subject: "The Problem of Public Utility Regulation." Speaker: Dr. William McClellan. Attendance 30.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MAY 21, 1920

ABBOTT, Royal W., Asst. Engineer, U. S. S. New Mexico; San Francisco, Cal.

APPEL, HENRY J., Erecting Engineer, Westinghouse Electric & Mfg. Co., 467, 10th Ave., New York; res., 52 Himrod St., Brooklyn, N. Y.

ASLAKSEN, EINAR, Draftsman, Lord Construction Co., 105 W. 40th St.; res., 142 W. 83rd St., New York, N. Y.

BAILY, BEN POWER, District Manager, Pacific Power & Light Co., 1st National Bank Building, Astoria, Ore.

*BALCH, CLEON F., Distribution & Engineering Div., T. M. E. R. & L. Co., Milwaukee; res., 830 Lake Ave., Racine, Wis.

BARKER, GUY A., Chief Engineer, Central Teresa Sugar Co., Ceiba Hueca, Oriente, Cuba.

BARNES, EDWIN H., Electrical Draftsman, Albert C. Wood, 1411 Walnut St.; res., 1318 N. Frazier St., Philadelphia, Pa,

BATT, CHARLES G., Chief Electrican, Utah Apex Mine, Bingham Canyon, Utah.

BEACOCK, VICTOR ALONZO, Electrical Engineer, Hydro-Electric Power Commission; res., 32 Dundonald St., Toronto, Ont.

BEMIS, EDWIN W., Instructor, Dept. of Electrical Engineering, Worcester Polytechnic Institute; res., 54 Fruit St., Worcester, Mass.

BENEDICT, ROY P., Manager, Chicopee Electric Light Department, Chicopee, Mass.

BINDLER, MICHAEL, Tester of Electrical Apparatus, British Thomson-Houston Co. Ltd.; res., 132 Murray Road, Rugby, England.

*Birkinbine, Olaf W., Asst. Engineer, Birkinbine Engineering Offices, Parkway Bldg., Broad & Cherry Sts., Philadelphia, Pa.

Bischoff, Louis G., Transmission & Protection Engineer, Central Union Telephone Co., 212 W. Washington St., Chicago, Ill.

Bissett, John W., Switchboard Operator, New York Edison Co., 122 Clinton St., New York; res., 39 Victor St., Yonkers, N. Y.

Bloch, Solly, Engineer, International General Electric Co.; res., 105 Seward Place, Schenectady, N. Y.

Bloomfield, Robert E., Consulting and Sales Engineer, Bagdad, Florida.

Bohmann, Robert B., Electrical Draftsman, Allis-Chalmers Mfg. Co., Milwaukee; res., 527 Beverly Road, Shorewood, Wis.

Bolen, Charles A., Plant Inspector, The Bell Tel. Company of Pa.; res., 308 Eicher Ave., Greensburg, Pa.

Bolton, Robert A., Asst. Professor of Drafting, Queen's University, Kingston, Ontario, Can.

Bordeaux, Ephriam P., Draftsman, Sanderson & Porter, 52 William St.; res., 204 W. 106th St., New York, N. Y.

Boss, Earle B., Leading Hand, Turbine Test, General Electric Co., W. Lynn; res., 1 Granite Road, Cliftondale, Mass.

Boutwell, Willard S., Service Engineer, Westinghouse Elec. & Mfg. Co.; res., 1729 Boylston Ave., Seattle, Wash.

Bowler, Willliam E., Sales Training Dept., Norton Company, Worcester; res., 4 Sampson St., Spencer, Mass.

Brodsky, Valdimir P., Electrical Draftsman, Switchboard Div., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Brown, Harrison G., Electrical Draftsman, U. S. Navy Yard, Portsmouth; res., West Rye, N. H.

Brown, Richard, Electrician, American Steel & Wire Co.; res., 217 Lincoln St., Worcester, Mass.

Bugbee, Ralph L., Electrical Designer, Lockwood, Greene & Co., Boston; res., 91 Lincoln St., Melrose, Mass.

Bundock, William A. W., Supervising Electrical Engineer, Dept. of Public Works; res., "Glenora", Henrietta St., Double Bay, Sydney, N. S. W., Aus.

Burman, Charles F., Engineering Dept., Wisconsin Telephone Co., 418 Broadway, Milwaukee, Wis.

Buxton, Vernon R., Sales Switchboard Engineer, Westinghouse Elec. & Mfg. Co., 10 High St., Boston Mass.

*Calligheris, John S., Mechanical Draftsman, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

Carpe, Allen, Student, Electrical Engineering, Columbia University; res., 321 W. 82nd St., New York, N. Y.

Church, Robert A., Service & Inspection Dept., Cutler-Hammer Mfg. Co., 50 Church St., New York, N. Y.

Cigrange, Joseph, Electrician, Electro Construction Co., 1222 St. Paul St., Baltimore, Md.

Clapp, Robert H., Development & Research Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Creim, Benjamin W., Test Dept., Bureau of Power & Light; res., 2025 Allesandro St., Los Angeles, Cal.

Cross, Raymond J., 1st Asst. Electrician, U. S. S. Leviathan, Hoboken, N. J.

Daunt, Charles A., Electrician, U. S. Government, U. S. Army Base, S. Boston; res., 26 Caton St., Mattapan, Mass. 26

Davis, Carlos, Rail Bonding Foreman, Hudson Valley Railway Co.; res., 18 Washington St., Glens Falls, N. Y.

Debman, Eugene R., Test Engineer, Westinghouse Elec. & Mfg. Co., 467 10th Ave., New York, N. Y.; res., 82 N. 15th St., E. Orange, N. J.

Dee, Thomas C., Instructor in Electrical Engineering, Iowa State College, Ames, Iowa.

de Locht, Victor Lagasse, Chief Engineer, Societe Generale de Chemins de Fer Economiques, 36 rue Capouillet, Bruxelles, Belgium.

Denny, Robert Cary, Operating Engineer, San Joaquin Light & Power Corp., H. & Tulare Sts., Fresno, Cal.

Dewey, Stuart J., Asst. Signal Engineer, C. C. C. & St. L. R. R., Cincinnati, Ohio.

Duff, John E., Squad Man & Checker, Sargent & Lundy, 1412 Edison Bldg., Chicago. Ill.

Dunderdale, Alston, Metropolitan Vickers Electrical Co., Trafford Park, Manchester; res., 11 Springfield Road, Altrincham, Cheshire, Eng.

Dupré, Valentine H., Engineer of Mech. & Elec. Methods, Western Electric Co., Hawthorne Station; res., 4123 W. Monroe St., Chicago, Ill.

Eaton, Frederick W., Elec Engg. Dept., Goodyear Tire & Rubber Co.; res., 1228 W. Pond View Ave., Akron Ohio.

Edmonds, Montrose, Quotation Clerk, General Electric Co., 1000 Lexington Bldg., Baltimore, Md.

Elstun, William P., Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Evans, James M., Salesman, Westinghouse Elec. & Mfg. Co.; res., 1277 Harrison Ave., Fresno, Cal.

Farmer, George L., Electrical Draftsman, Panama Canal, Balboa Heights, C. Z.

Fay, Carl J., Engineer, Westinghouse Electric Products Co., Mansfield, Ohio.

*Ferguson, Alan H., Power Plant Draftsman, Commonwealth Edison Co.; res., 5403 Prairie Ave., Chicago, Ill.

Fisher, Mordaunt J. M., Foreign Student Course, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Flaherty, Leonard T., Manager, Picton County Electric Co., Stellarton, N. S.

Ford, James E., Senior Testman, New England Tel. & Tel. Co.; res., 271 Powder House Blvd., Somerville, Mass.

Foss, Carl E., Salesman, Victor Electric Corp.; res., 4109 Washington Blvd., Chicago, Ill.

Fowler, Herman M., Electrical Engineer, Wesinghouse Elec. & Mfg. Co.; res., 5515 Brandon St., Seattle, Wash.

French, Ralph W., Salesman, Heavy Traction Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Frick, Clifford H., Supervisor of Operation, Hauto Steam Electric Generating Station, Hauto; res., 238 E. Broad St., Tamaqua, Pa,

Fry, Howard M., Asst. Professor, Physics Dept., Lehigh University; res., 726 Avenue H., Bethlehem, Pa.

*Fryburg, Warren, (Partner), Effandee Motor Trucking Exchange, 32 Union Square; res., 159 W. 77th St., New York, N. Y.

Geder, John J., Electrical Estimating Engineer, Allis-Chalmers Mfg. Co., West Allis, Wis.

Gemmill, Melvin E., Electrican, Bethlehem Shipbuilding Corp., Sparrow Point; res., 3522 E. Fairmount Ave., Baltimore, Md.

Ghosh, Jagabandhu, Pupil Engineer, Charing Cross, West End & City Electricity Supply Co., Stratford; res., 58 Redcliffe Road, London, S. W. 10, Eng.

Gieselberg, George H., Chief Engineer & Mechanical Supt., Gimbel Brothers, 6th Ave. & 33rd St., New York; res., 683 Briggs Ave., Richmond Hill, N. Y.

*Gilchrist, Frederick W., Sales Engineer, The Cutler-Hammer Mfg. Co.; res., 222 11th St., Milwaukee, Wis.

Grunfield, Maurice, 126 East 95th Street, New York, N. Y.

Grunsky, Clotilde, Associate Editor, *Journal of Electricity*, 531 Rialto Bldg., San Francisco, Cal.

Harris, Leonard F., Engineering Asst., New York Telephone Co., 195 Broadway; res., 300 E. 143rd St., New York, N. Y.

Harvey, Lloyd B., Electrical Worker, Instrument Dept., U. S. Navy Yard, Portsmouth; res., Greenland, N. H.

Hatz, Earl W., Engineering Div., Electrical Distribution Dept., Milwaukee Elec. Ry. & Light Co., Milwaukee, Wis.

Hecht, J. Bernard, General Construction Engineer, Tri-State Tel. & Tel. Co.; res., 1839 Ashland Ave., St. Paul, Minn.

Heckman, Chester L., Salesman, Westinghouse Electric & Mfg. Co., 1012 Park Bldg., Worcester, Mass.

*Heffner, Roy E., Instructor of Electrical Engineering Dept., Sibley College, Cornell University, Ithaca, N. Y.

Henritze, Richard James, Supervisor, Coil and Insulation, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Hodge, Thomas J., Inspector, Engineering Dept., Potomac Electric Power Co., Washington; res., 215 Buffalo Ave., Takoma Park, Washington, D. C.

*Hoey, William B., Research Work, Engg. Dept., Electric Service Supplies Co., 17th & Cambria Sts., Philadelphia, Pa.

Hollenbeck, Charles H., Special Apprentice, N. Y., N. H. & H. R. R., Van Nest & Matthews Ave.; res., 79 Mahlstedt Place, New Rochelle, N. Y.

*Howe, Harvey W., Manager, Engineering Dept., Beckett Electric Co., 206 Linz Bldg., Dallas, Texas.

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JAMES, HERBERT M., Electrical Engineer, Hudson Coal Co.; res., 318 Taylor Ave., Scranton, Pa.

JOHNSON, EARL A., Junior Electrical Engineer, Transit Construction Commission, Electrical Laboratory, 49 Lafayette St., New York, N. Y.

KALAPESI, M. J., H. M. Government Electrican, The Residency, Tarshyne, Aden., Arabia.

KALMBACH, MAURICE F., Transmission & Protection Engineer, Wisconsin Telephone Co.; res., 354 37th St., Milwaukee, Wis.

KELLEY, THOMAS C., Testing Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 414 Montview Place, Wilkinsburg, Pa.

KEYSER, WILLIAM H., Sub-Foreman, Electric Construction, Puget Sound Traction, Light & Power Co.; res., 2426 W. 60th St., Seattle, Wash.

KHAN, M. ALI, Electrical Engineering, General Electric Co.; res., 21 Ferry St., Schenectady, N. Y.

KIDWELL, HERBERT W., Asst. Electrical Engineer, W. &. O. D. Railway, 3611 M St., Washington, D. C.

KILLAM, LAFAYETTE W., Foreman, Armature Winder, Westinhouse Elec. & Mfg. Co., New York; res., 1081 71st St., Brooklyn N. Y.

KING, EARL B., Electrolysis Engineer, Central Union Telephone Co.; res., 2934 N. Penn St., Indianapolis, Ind.

KIRBY, JOSEPH H., Electrical Contracting, H. B. Hustin & Son, Jackson, Tenn.

KNICKERBOCKER, WALTER G., Office Manager, H. F. Fleming Construction Co., Marysville, Mich.

LAUBER, CALVIN G., Engineer, National Board of Fire Underwriters, 76 William St., New York, N. Y.

LEITE, ARNALDO F., Electrical Engineer, Wilkinsburg, Pa.

LEWTHWAITE, FRED A., Substation Engineer, Public Works Dept., Addington Substation, Christchurch, N. Z.

*LIKELY, ROBERT D., Testing Dept., General Electric Co.; res., 33 N. Ferry St., Schenectady, N. Y.

LINDZEY, JOHN O., Tester, Diehl Manufacturing Co., Elizabethport; res., 423 Park Ave., Plainfield, N. J.

LONG, ORVILLE F., Electrical Engineer, Kelsey Wheel Co. Inc., Memphis, Tenn.

LOOS, ALDO H., Electrical Draftsman, Kansas City Light & Power Co.; res., 1829 E. 7th St., Kansas City, Mo.

LOSHING, CLEMENT K., Elec. Engg., Cleveland Electric Illuminating Co., 308 Illuminating Bldg., Cleveland, Ohio.

LOVETT, FREMONT L., Distribution Engineer, Worcester Electric Light Co., 66 Faraday St., Worcester, Mass.

*LOWELL, GLEN J., Electrical Engineer, General Electric Co.; res., 3 Swan St., Schenectady, N. Y.

LUICHINGER, MARTIN J., Field Engineer (Long Distance Lines), Central Union Tel. Co.; res., 615 W. 32nd St., Indianapolis, Ind.

MACDONALD, KENNETH V., Lock Operator (Electrical), New York State Barge Canal; res., 152 W. 3rd St., Fulton, N. Y.

MACDONALD, MARTIN W., System, Operator, Hagerstown & Frederick Co., & Operated Co's. Hagerstown, Md.

MACNELLEY, CHARLES J., Material Foreman, The Panama Canal, Balboa, C. Z.

MACPHERSON, KENNETH P., Lecturer, in Electrical Engineering, Queen's University, Kingston, Ont.

MAGEE, FRANK, L., Salesman, Aluminum Company of America; res., 196 Norton St., New Haven, Conn.

MAGNUSON, AXEL H., Chief Electrician, The Graton & Knight & Mfg. Co., 344 Franklin St.; res., 19 Altmont Ave., Worcester, Mass.

MAKOUS, LAWRENCE, Draftsman, Elec. Dept., Allis-Chalmers Mfg. Co., W. Allis, Wis.

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MAXWELL, JOSEPH H., Asst. Supt. of Testing & Standardization, Elec. Light Dept., S. M. C., Sydney, Australia.

McCLEERY, HAROLD L., Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1128 Franklin Ave., Wilkinsburg, Pa.

McCORMICK, FRED J., Outside Plant Engineer, Wisconsin Telephone Co.; res., 465 Frederick Ave., Milwaukee, Wis.

McDONALD, JAMES W., Engineering Asst., Public Service Electric Co., Newark; res., 90 Hollywood Ave., E. Orange, N. J.

McDOUGALL, JAMES C., Engineer, Westinghouse Electric & Mfg. Co., 1400 Alaska Bldg., Seattle, Wash.

MEYERS, PHILIP M., Supt., Ferracute Machine Co.; res., 50 North Giles St., Bridgeton, N. J.

MILLER, HENRY J., General Electric Co.; res., 6159 Kenwood Ave., Chicago, Ill.

MINTZNER, WATKINS F., Construction Engineer, Service Dept., Canadian Westinghouse Co. Ltd., Hamilton, Ont., Canada.

MISSO, GEORGE E., Asst. Engineer, Colombo Electric Tramways & Lighting Co., Colombo, Ceylon.

MITCHELL, HAROLD J., Investigating Engineer, Westinghouse Elec. & Mfg. Co., 467 10th Ave., New York; res., 42 2nd St., Elmhurst, N. Y.

MONTGOMERY, JOHN V., Engineer, Electrical Division, Engg. Dept., Dwight P. Robinson & Co., Inc., 61 Broadway, New York, N. Y.

MOORE, ERIC M., Local Manager, Washington Coast Utilities & Vashon L. & P. Co., Portage, Wash.

MOORHEAD, O. B., President & Chief Engineer, Moorhead Laboratories Inc.; res., 15 26th Ave., San Francisco, Cal.

MOREHOUSE, ADEN K., Division Equipment Foreman, Pacific Tel. & Tel. Co., Sheldon Bldg., San Francisco, Cal.

MORGAN, FRANK I., Electrical Inspector, Penn. Water & Power Co., Holtwood, Pa.

MORRONI, ANTHONY J., Chief Electrician, Central Armature Works, 635 D St., N. W., Washington, D. C.

MOSMAN, CHARLES F., Electrical Testing & Laboratory Work, Factory Mutual Fire Insurance Co. Laboratories, Boston; res., 29 Webster St., Atlantic, 71, Mass.

MULKEY, SAM F., Wiremans' Helper, Union Electric Light & Power Co.; res., 3963 W. Pine St., St. Louis, Mo.

MURRAY, WILLIAM ARTHUR, Intructor in Electrical Engineering, University of Idaho; res., 425 Third St., Moscow, Idaho.

MYERS, CLYDE J., Salesman, Electric Motors, Holtzer-Cabot Electric Co., 1051-52 Book Bldg., Detroit, Mich.

NASH, FREDERICK H., Research Engineer, Empire Gasoline Co., Bartlesville, Okla.

NELSON, EDWARD L., Engineering Dept., Western Electric Co., 463 West St., New York, N. Y.

NEUSTEDTER, WALTER J., Engineer, Cutler-Hammer Mfg. Co.; res., 1207, 25th St., Milwaukee, Wis.

NEWTON, WILLIAM J., Electrical Engineer & Patent Attorney, Harvey Hubbell, Inc., Bridgeport, Conn.

NISTRY, NUSSERWANJI R., Statistician, Tata Hydro-Electric Power Supply Co., Ltd., Bombay 2, India.

NOPPEL, EDWARD P., Asst. Mechanical Engineer, American Railways Co.; res., 2508 So. Colorado St., Philadelphia, Pa.

NORCROSS, JOSIAH C., Asst. Supt., Installations Dept., Edison Elec. Ill. Co. of Boston, 39 Boylston St., Boston (10), Mass.

O'DEA, MATTHEW F., District Office Inspector, Cutler-Hammer Mfg. Co., 77 Franklin St., Boston, Mass.

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POMEROY, JOSEPH GEORGE, Electrician, City Light Dept., County-City Bldg., Seattle, Wash.

Poupart, Ernest, Electrical Engineer, Lake Shore Mines, Ltd., Kirkland Lake, Ontario, Can.

Pride, Alfred W., Engineer, Electric Auto-Lite Corp.; res., 356 Winthrop St., Toledo, Ohio.

Reading, Robert S., Electrical Engineer, Stone & Webster, Houston, Texas.

*Reed, Myron G., Local Manager, Central Mexico Light & Power Co., Irapuato, Gto., Mexico.

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Rosen, Nathan, Electrical Draftsman, U. S. Navy Yard, Portsmouth, N. H.

Ross, Harold D., Electrical Engineer, General Electric Co.; res., 65 Livingstone Ave., Pittsfield, Mass.

Ross, Lindsley W., Telephone Engineer, The Pacific Tel. & Tel. Co.; res., 590 Main St., Portland, Ore.

*Rothschild, Harold L., Sales Engineer, St. Paul Electric Co., St. Paul, Minn.; res., Le Mars, Ia.

Rushton, Frederick, Switchboard Operator, Hydro Electric Power Commission of Ontario; res., 747 Annette St., Toronto, Ont.

Scott, Bernard W., Asst. to Electrical Engineer, American Woolen Co., Boston; res., 17 Saratoga St., Lawrence, Mass.

Seabra, José R., Electrical Engineer, Brazilian Government: Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Shaw, J. B., Electrican, West Penn Power Co.; res., 118 Truby St., Greensburg, Pa.

Simmons, Moses H., General Electric Works, The New Jersey Zinc Co., Franklin, N. J.

Sinclair, Charles G. Jr., Telephone Engineer, New York Telephone Company, 203 Broadway, New York, N. Y.

*Singh, Charnjit, Priest, Stockton, Cal.

Smith, Charles D., Electrical Foreman, Engg. Dept., E. I. Du Pont de Nemours Co., So. Windham, Maine.

Smith, Charles G., Chief Electrican, Cosden & Co., West Tulsa Refinery; res., 115 Frisco St., W. Tulsa, Okla.

Smith, Don F., Transmission Engineer, Pacific Tel. & Tel. Co., 507 Sheldon Bldg., San Francisco, Cal.

Smith, Frederick William, Electrical Dept., St. Elizabeth's Hospital, Washington, D. C.

Smith, Glen H., Engineer, Outside Construction, City of Seattle, Lighting Dept.; res., 4269 Linden Ave., Seattle, Wash.

Snow, Arthur F., Service Engineer, Worcester Electric Light Co.; res., 209 Chandler St., Worcester, Mass.

Snow, Harold M., Operator, Hartwig Theatre; res., 910 S. Washington St., Dillon, Mont.

Steortz, Charles M., Foreman, Battery Charging Station, Panama Canal, Cristobal, C. Z.

Stevens, Vergil, Engineering Dept., Tri-State Tel. & Tel. Co., Merriam Park, St. Paul, Minn.

Strachan, Harley A., Production Dept., Century Electric Co.; res., 4311 Lee Ave., St. Louis, Mo.

Stubinger, Eugene McAlpin, Engineering Draftsman, 1530 Healey Bldg., Atlanta, Ga.

Sturtevant, Benjamin J., Electrical Engineer, The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

Sullivan, M. E., Construction Supt., General Electric Co.; res., 3523 Bosworth Ave., Chicago, Ill.

Swann, Edwin H., Telephone Engineer, Bell Telephone Company of Pa.; res., 4911 Walnut St., Philadelphia, Pa.

Swicker, Lester C., Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Takahashi, Kanejiro, Electrical Engineer, Yokohama Electric Wire Works, Yokohama, Japan.

Temme, Alfred M., Electrical Engineer, Westinghouse Elec. & Mfg. Co., 467 10th Ave., New York; res., 2511 Woodbine St., Ridgewood, N. Y.

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Torrens, Robert J., Electrical Engineer, U. S. Naval Observatory, Washington, D. C.

Townsend, Herbert K., Chief Clerk to Electrical Engineer, S. F. O. T. Railways, 22nd & Grove Sts., Oakland, Cal.

Transtrom, Henry L., Electrical Worker, Central Armature Works, 7 & D Sts.; res., 6615 1st St., N.W., Washington, D.C.

Tucker, Francis, Manager, Wiring Dept., Standard Electrical Elevator Co., 118 E. Pratt St., Baltimore, Md.

Tufty, Harold G., Graduate Student, University of Wisconsin; res., 213 Lake St., Madison, Wis.

Tyzzer, Howard J., Radio Engineer, American Radio & Research Corp., Medford Hillside; res., 13 Upham St., Melrose, Mass.

Underhill, John Delmar, Sales Manager, The Okonite Co., Passaic, N. J.

Van Dorn, Alma L. M., Physical Laboratory Helper, Bureau of Standards, Washington, D. C.

Viets, Floyd H., Division Engineer, Research Corporation, Anaconda, Mont.

Von Lossow, Rainey L., Engineer, Service Dept., Westinghouse Elec. & Mfg. Co., 560 1st Ave. So., Seattle, Wash.

Waters, Basil W., Jr., Construction Engineer, Kentucky & W. Virginia Power Co., Hazard, Ky.

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*West, Benjamin, Post Graduate Student, Mass. Inst. of Technology, Cambridge, Mass.

White, Daniel W., Tester, General Electric Co., West Lynn, Mass.

Whitney, William G., Special Apprentice, N. Y. N. H. & H. R. R., Van Nest Elec. Repair Shop, New York; res., 79 Mahlstedt Place, New Rochelle, N. Y.

Wilkinson, Winfred D., Engineering Dept., Power Construction Co., 35 Harvard St., Worcester, Mass.

*Wilmeth, Roscoe, Electrical Engineer of Engineering Laboratory, Stackpole Carbon Co.; res., 220 Brusselles St., St. Marys, Pa.

Wood, Raymond, Sales Correspondent, Wagner Electric Mfg. Co.; res., 1371 Goodfellow Ave., St Louis, Mo.

Wyman, Hugh K., Estimates Engineer, Canadian General Electric Co.; res., 588 Manning Ave., Toronto, Ont., Can.

Yerbury, Charles W., President, McIntire Corporation; res., 83 Wilson Ave., Newark, N. J.

Young, A. R., Laboratory Work, U. S. Navy Yard, Portsmouth, N. H.; res., Kittery, Maine.

*Young, Charles S., Distribution Engineer, The Lehigh Valley Light & Power Co., Allentown, Pa.

*Young, Warren G., Engineering Asst., Power Motor Engg. Dept., General Electric Co., Pittsfield, Mass.

Yung, Chi-wei, Electrical Engineer, Power Station Work, Mow Sing Flour Milling Co., 49 Ave. Edward VII, Shanghai, China

*Zimmermann, Arnold, Equipment Engineering, Roth Bros. & Co.; res., 5211 Indiana Ave., Chicago, Ill.

Zundel, Amdrew H., Salesman, Westinghouse Elec. & Mfg. Co., 165 Broadway, New York; res., 60 Anderson St., New Rochelle, N. Y.

Total 216

*Former enrolled student

ASSOCIATES REELECTED MAY 21, 1920

Bridges, J. Earle, District Equipment Foreman, Michigan State Telephone Co., 406 Central State Bldg., Jackson, Mich.

D'Huny, Fernand Emile, Central Office Engineer, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

Gilman, Ralph E., Electrical Engineer, Westinghouse Electric & Manufacturing Co., E. Pittsburgh, Pa.

Hurley, Wallace P., Sales Engineer, Westinghouse Elec. & Mfg. Co., 165 Broadway, New York, N. Y.

Nye, Henry V., Sales Engineer, Allis-Chalmers Mfg. Co.; res., 758 75th Ave., W. Allis, Wis.

Phillips, Edwin T., Supt. of Power, The Eastern Connecticut Power Co.; res., 55 Broad St., Norwich, Conn.

Spencer, Fredrick A., Professor of Electrical Engineering, Norwich University, Northfield, Vermont.

MEMBERS ELECTED MAY 21, 1920

ANCIAUX, LOUIS, Manager, Arequipa Tramways Co., Casilla 176, Arequipa, Peru, S. A.

CURTIS, EGBERT H., Estimating Engineer, Lord Electric & Lord Construction Co., 105 West 40th St., New York, N. Y.

BOWMAN, EDWARD C., Engineer of Transmission, Long Lines Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

DODGE, HARRY A., Electrical Engineer, Lockwood, Greene & Co., 101 Park Ave., New York, N. Y.

EMERSON, CHERRY L., Power Engineer, Robert & Co., Tufts Bldg., Atlanta, Ga.

FULLER, CARL T., Engineer, Edison Lamp Works, General Electric Co., Harrison, N. J.

FYKE, J. LOWELL, Asst. Supt., Electrical Dept., Allis-Chalmers Mfg. Co., W. Allis; res., 480 52nd St., Milwaukee, Wis.

HALL, THEODORE, Engineer, Research Dept., Sperry Gyroscope Co., Manhattan Bridge Plaza, Brooklyn, N. Y.

HARDY, GEORGE M., Supt., Distribution & Service, Worcester Electric Light Co.; res., 37 June St., Worcester, Mass.

JOHNSON, CLARENCE C., Vice-President in charge of Engineering & Plant, American District Telegraph Co., 30 Church St., New York, N. Y.

PACKWOOD, GEORGE H., JR., Electrical Engineer, G. E. Smith & Company, 2073 Railway Exchange Bldg., St. Louis, Mo.

PEARSON, HAROLD J. C., Asst. to Manager, and in Charge of Electrical work, Walker Electric & Plumbing Co., Atlanta, Ga.

PENN, MARION, Plant Engineer, Public Service Electric Co. of N. J., Essex Station, Point-no-Point, Newark, N. J.

PERCIVAL, HARRY S., Engineer of Outside Plant. Long Lines Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

PERRIN, CECIL M., Distribution Engineer, Municipal Electricity Dept., Shanghai, China.

POMEROL, LAURENT, Sub-Director, Energia Electrica de Cataluna; res., 305 Mallorca 4°-2a, Barcelona, Spain.

SCHNABELT, FRANK J., Works Engineer, Western Electric Co. Inc., Hawthorne Plant; res., 930 N. Lawler Ave., Chicago, Ill.

SMITH, MARSDEN C., Engineer in charge of Electrical Div., Dept. of Public Utilities, City of Richmond, Richmond, Va.

TRANSFERRED TO GRADE OF MEMBER MAY 21, 1920

ATKINSON, KERR, Engineer, with Roderick D. Donaldson, New York, N. Y.

CANADA, WILLIAM J., Electrical Engineer, Stone & Webster, Boston, Mass.

FAIR, RICHARD H., Outside Plant Engineer, Bell Telephone System, Northwestern Group, Omaha, Neb.

HOWLAND, RALPH B., Assistant Electrical Engineer, Dwight P. Robinson & Co. Inc., New York, N. Y.

IVES, JOHN NASH, Electrical Engineer, Lockwood, Greene & Co., Boston, Mass.

McEACHRON, KARL B., Research Assistant, Engineering Experiment Station, Purdue University, Lafayette, Ind.

REGAL, A. P., Electrical Engineer, Philadelphia Rubber Works Co., Akron, O.

SCHLUSS. KURT C., Supt. of Power & Equipment, Tacoma Ry. & Power Co., Puget Sound Electric Ry., Puget Sound Traction Lt. & Pr. Co. (Tacoma Div.), Tacoma, Wash.

STANFORD, F. C., Chief Electrician, Cleveland Cliffs Iron Co., Ishpeming, Mich.

STELZNER, W. B., Professor of Electrical Engineering, University of Arkansas, Fayetteville, Ark.

THORNTON, FRANK, JR., Chief Engineer, Westinghouse Electric Products Co., Mansfield, O.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at meetings held May 10 and 17, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

BIBBINS, JAMES R., Supervising Engineer, The Arnold Co., Chicago, Ill.

BYLLESBY, HENRY M., President, H. M. Byllesby Co., President, Standard Gas & Electric Co., Chicago, Ill.

CALDWELL, HARRY L., Engr. of Elec. Distribution, Public Service Co. of Northern Illinois, Chicago, Ill.

CRAVATH, JAMES R., Member of firm, Fowle & Cravath, Chicago, Ill.

DEL MAR, WILLIAM A., Chief Engineer, Habirshaw Electric Cable Co., New York, N. Y.

ELLS, FREDERICK W., Chief Engineer, Northwestern Mfg. Co., Milwaukee, Wis.

GEAR, HARRY B., Engr. of Distribution, Commonwealth Edison Co., Chicago, Ill.

GRAHAM, EARL A., General Manager & Chief Engineer, Compania Panamena de Fuerza y Luz, Ancon, C. Z.

HALL, CHESTER I., Engineer, Experimental Laboratory, General Electric Co., Fort Wayne, Ind.

KING, ARTHUR C., President, Illinois Appraisal Co., Chicago, Ill.

MILTON, TALIAFERRO, Manager, Chicago Office, Electric Storage Battery Co., Chicago, Ill.

MORTENSEN, NIELS L., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

MORTENSEN, SOREN H., Electrical Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

MOUNTAIN, JOHN T., Asst. to Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill.

REINHARD, LOUIS F., Chief Engineer, Mechanical Appliance Co., Milwaukee, Wis.

SCHWEITZER, EDMUND O., Chief Testing Engineer, Commonwealth Edison Co., Chicago, Ill.

To Grade of Member

ADAMS, HARRY H., Supt. Shops & Equipment, Chicago Surface Lines, Chicago, Ill.

ALLEN, N. L., Chief Electrical Engineer, American Zinc Lead & Smelting Co., Mascot, Tenn.

ANNETT, FRED A., Associate Editor *Power*, New York, N. Y.

BACON, FRANK R., President, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

BELL, WILLIAM I., Mechanical & Electrical Engineer, South Park Commissioners, Chicago, Ill.

BOOTH, WILLIAM K., Secretary & Chief Engineer, Booth Electric Furnace Co., Chicago, Ill.

BOWMAN, DONALD, Engineer of Apparatus & Materials, Commonwealth Edison Co., Chicago, Ill.

BRACK, G. S., Electrical Engineer, The Sanitary District of Chicago, Chicago, Ill.

BRITTON, JOHN A., Vice-President & General Manager, Pacific Gas & Electric Co., San Francisco, Cal.

BROWN, CARLTON E., Meter Engineer, Commonwealth Edison Co., Chicago, Ill.

BURR, FRANK D., Power Engineer, Denver Gas & Electric Light Co., Denver, Colo.

CRELLIN, EARLE A., Electrical Engineer with Leland S. Rosener, San Francisco, Cal.

CURTIS, LESLIE F., Asst. Professor of Electrical Engineering, University of Washington, Seattle, Wash.

d'HUMY, FERNAND E., Central Office Engineer, Western Union Telegraph Co., New York, N. Y.

EDWARDS, STANLEY R., Editor, *Telephony*, Chicago, Ill.

FLANDERS, MILTON M., Charge Dept. of Electrical Tests, Bliss Electrical School, Washington, D. C.

FLEET, ARTHUR H., Manager, Specialty Dept., Cutler-Hammer Mfg. Co., Milwaukee, Wis.

FOX, EDWIN G., Electrical Engineer, Steel & Tube Co. of America, Indiana Harbor, Ind.

GILMAN, RALPH E., Electrical Engineer, Westinghouse Electric & Mfg, Co., E. Pittsburg, Pa.

HUBBARD, FRANK H., Patent Attorney, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

JACKSON, WILLIAM A., President, W. A. Jackson Co., Chicago, Ill.

JOHNSON, ALVIN W., Elec. Engr. in Charge General Construction, General Electric Co., Chicago, Ill.

KAMMERMAN, JOHN O., Asst. Professor of Electrical Engineering, University of Wisconsin, Madison, Wis.

LAUE, GILBERT E., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

LUNN, ERNEST, Chief Electrician, The Pullman Co., Chicago, Ill.

McHENRY, Manager, Walkerville Hydro-Electric System, Walkerville, Ont.

MORSE, ROBERT E., Engineer-in-Charge, Henry R. Kent & Co., Rutherford, N. J.

NYE, HENRY V., Special Sales Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

O'CONNOR, ALBERT, Manager, Switchboard Dept., Westinghouse Elec. & Mfg. Co., Boston, Mass.

OSTRANDER, JOHN K., Electrical Engineer, Dwight P. Robinson & Co., New York, N. Y.

PARKER, ROSS I., Apparatus Sales Dept., General Electric Co., Chicago, Ill.

PETROWSKY, JOHN F., Designing Engineer, A. C. Engineering Dept., Crocker-Wheeler Co., Ampere, N. J.

REINHARD, GUSTAV A., Asst. Chief Engineer, Mechanical Appliance Co., Milwaukee, Wis.

RUSSEL, FRANK J., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

SCHOU, THEODORE, Chief Engineer, Ideal Electric & Manufacturing Co., Mansfield, O.

SEIBERT, WILLIAM J., Asst. Chief Electrician, General Electric Co., Erie, Pa.

SPENCER, FREDERICK A., Professor of Electrical Engineering, Norwich University, Northfield, Vt.

WADE, HENRY N., Development Engineer (Electrical), Cutler-Hammer Mfg. Co., Milwaukee, Wis.

WATT, GEORGE Y., Century Electric Co., St. Louis, Mo.

WILKINSON, C. T., Engineer & Manager, Milliken Manufacturing Syndicate, London, England

WILKINSON, KENNETH L., Charge Foreign Wire Relations, American Telephone & Telegraph Co., New York, N. Y.

WOODCOCK, LANCELOT R., Resident Engineer, Riegos y Fuerza del Ebro, Barcelona, Spain

WURTH, WILLIAM, Engineer Statistics, The Peoples Gas Light & Coke Co., Chicago, Ill.

WYNNE, VALENTINE C., Consulting Engineer, Albany, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member, objecting to the election of any of these candidates should so inform the Secretary before June 30, 1920.

Addis, Judd, Seattle, Wash.
Almquist, Paul B., Seattle, Wash.
Anderson, John F., Bellville, Ont.
Anglemyer, Wilbur F., Chicago, Ill.
Andresen, Kilmar, Chicago, Ill.
Anson, Stuart, M., Worcester, Mass.
Arenberg, Albert L., Chicago, Ill.
Bakesef, Samuel, (Member), Los Angeles, Cal.
Barmack, Boris J., Chicago, Ill.
Bates, Albert W., New Haven, Conn.
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Bouska, James W., Chicago, Ill.
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Walker, Richard, Atlanta, Ga.
Wallis, Charles R., Seattle, Wash.
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Wiswell, Frederick G., Seattle, Wash.
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Wright, Paul L., New York, N. Y.
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Total 253

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da Fonseca Telles, Francisco E., S. Paulo, Brazil
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Ravut, Camille L. M., Paris, France
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Wood, William W., Birmingham, Eng.

Total 25

STUDENTS ENROLLED May, 21 1920

MAY 21, 1920

11436 Haigh, Richard A., University of Michigan
11437 Gaines, Le Grand A., Jr., University of Michigan
11438 Brede, Erwin F., University of Michigan
11439 Merritt, Frank B., Rutgers College
11440 Bolles, Carleton F., Worcester Polytechnic Institute
11441 Leonard, Richard S., Worcester Polytechnic Institute
11442 Dunbar, John R., McGill University
11443 Corrigan, Thomas P., New York Electrical School
11444 Landwersilk, Edward J., Pratt Institute
11445 Parrott, John A., Catholic University of America
11446 Holland, Norman N., Johns Hopkins University
11447 Brewster, Louis C., Case School of Applied Science
11448 Williams, Joseph S., Case School of Applied Science
11449 Childs, Maynard H., Case School of Applied Science
11450 Votypka, Yaro H., Case School of Applied Science
11451 Nyerges, William S., Case School of Applied Science
11452 Stone, Leland, Worcester Polytechnic Institute
11453 Nein, Harry R., Pennsylvania State College
11454 Stover, Earl B., University of Illinois
11455 Dawson, Heber W., McGill University
11456 Morse, Lyle J., Worcester Polytechnic Institute
11457 Graff, Milton W., Worcester Polytechnic Institute
11458 Douglas, Forest M., Jr., Worcester Polytechnic Institute
11459 Meyrick, Gordon S., University of Wisconsin
11460 Keller, John J., Purdue University
11461 Brown, Campbell A., Purdue University
11462 Kaufman, Aaron R., Purdue University
11463 Mitchell, Chester F., Purdue University
11464 Freezee, Walter D., Purdue University
11465 Moore, Earl R., Purdue University
11466 Bailey, George H., Purdue University
11467 Meissner, Herman A., Case School of Applied Science
11468 King, Harold, Case School of Applied Science
11469 Friedman, Bernhard D., Case School of Applied Science
11470 Backus, Ray A., Michigan Agricultural College
11471 Moore, Edward R., Pennsylvania State College
11472 Cooley, Gilbert, University of Minnesota
11473 Inouye, Noborn, Johns Hopkins University
11474 Ault, E. Stanley, Johns Hopkins University
11475 Spartana, Anthony R., Johns Hopkins University
11476 Anderson, Arvid E., Worcester Polytechnic Institute
11477 Beil, Cecil N., Oklahoma A. & M. College
11478 Black, Harold S., Worcester Polytechnic Institute
11479 Arthur, Stanley W., Worcester Polytechnic Institute
11480 Parnell, Eric, McGill University
11481 Bagby, Raymond J., Worcester Polytechnic Institute
11482 Whelen, Morland P., McGill University
11483 Brush, Waite S., Rensselaer Polytechnic Institute
11484 Bourne, Roland B., Rensselaer Polytechnic Institute
11485 Douglass, Dwight, Rensselaer Polytechnic Institute
11486 Guernsey, Charles W., Rensselaer Polytechnic Institute
11487 La Riviere, John B., Rensselaer Polytechnic Institute
11488 Ketcham, Earl D., Rensselaer Polytechnic Institute
11489 Martin, Edmund B., Rensselaer Polytechnic Institute
11490 Martinez, Lauro C., Rensselaer Polytechnic Institute
11491 Michon, Alfred E., Rensselaer Polytechnic Institute
11492 Mitchell, Erwin H., Rensselaer Polytechnic Institute
11493 Raynor, Lucian B., Rensselaer Polytechnic Institute
11494 Reynolds, James J., Rensselaer Polytechnic Institute
11495 Smith, Reginald S., Rensselaer Polytechnic Institute
11496 Smith, Seneca S., Jr., Rensselaer Polytechnic Institute
11497 Stafford, John K., Rensselaer Polytechnic Institute
11498 Snyder, William B., Rensselaer Polytechnic Institute
11499 Stamper, Hamilton A., Rensselaer Polytechnic Institute
11500 Tate, F. Spencer, Rensselaer Polytechnic Institute
11501 Trevett, Harold N., Rensselaer Polytechnic Institute
11502 Kurtz, Henry J., Michigan Agricultural College
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11506 Kaehni, Frank J., Case School of Applied Science
11507 Van Sickle, Miles E., Carnegie Institute of Technology
11508 Johnston, Lloyd E., Johns Hopkins University
11509 Isaac, Rosa D., University of California
11510 Adelson, Abraham M., University of Washington
11511 Blakeley, Loren E., California Institute of Technology
11512 Abbott, L. Emerson, Ohio Northern University
11513 Biggin, Harold L., Alabama Polytechnic Institute
11514 Gentzel, Paul M., Pennsylvania State College
11515 Hunting, Harold S., Worcester Polytechnic Institute
11516 Ashley, David P., Worcester Polytechnic Institute
11517 Reimann, Edward C., Armour Institute of Technology
11518 Pope, Robert, Stevens Institute of Technology
11519 Strauss, Jacob S., Cooper Union
11520 Fuog, Arnold T., Armour Institute of Technology
11521 Duck, Emerson, School of Engineering of Milwaukee
11522 Martin, Alvin A., School of Engineering of Milwaukee
11523 Oliver, Arnold J., School of Engineering of Milwaukee
11524 Karin, Harvey G., School of Engineering of Milwaukee
11525 Grob, John J., School of Engineering of Milwaukee
11526 Marshall, Russell H., Franklin Union Classes
11527 Deering, Lawrence E., University of Maine
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11529 Haatanen, George, Tri-State College of Engineering
11530 Hoidahl, Edward M., Tri-State College of Engineering
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11553 Butler, Henry R., University of Maine
11554 Barnard, Walter F., Pennsylvania State College
11555 Brewster, Oswald C., Cornell University
11556 Will, Irving M., Worcester Polytechnic Institute
11557 Marion Frederick R., Stevens Institute of Technology
11558 Schippel, Walter H., McGill University
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11561 Moir, James G., Jr., Massachusetts Institute of Technology
11562 Kemp, Erford C., Wentworth Institute
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11571 Smith, Harry L., Pratt Institute
11572 Cook, Jerome E., Pratt Institute
11573 Wahmann, Charles H., Johns Hopkins University
11574 Goss, Raymond W., Carnegie Institute of Technology
11575 Harris, Everett, Pratt Institute

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*Henry G. Stott, 1907-8.
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Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.

*Deceased.

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Electrical Characteristics of the Suspension Insulator--II.

The Line Insulator at the Higher Voltages

BY F. W. PEEK, Jr.
General Electric Co., Pittsfield, Mass.

IT is the purpose of this paper to review the duties of the line insulator at voltages above 100 kv. and compare them with the duties imposed by the lower voltages. It seems desirable to do this at the present time in order to predict the reliability of future high-voltage lines as compared with those at present in operation, and to point out what changes, if any, are necessary in present practise. The discussion is based in general upon data and operating experiences of many investigations and, in particular, upon extensive investigations made by the author during the last few years. Quite complete data on that phase of the author's investigation dealing with voltage distribution will be given.

Present Status

At the present voltages the problem is primarily a mechanical one. Mechanically, porcelain would never be selected as a line support. It is unreliable in tension, subject to cracking, and if made in large pieces subject to porosity. The greatest care is necessary in manufacture to secure a uniform, tough, non-brittle material, free from porosity. Unfortunately it is the only material that we know of at the present time that will withstand the weather without the carbonization and deterioration of organic compounds under the electrical stress.

Generally after three to five years of more or less successful operation, insulators selected by the most careful electrical tests begin to fail rapidly. There are of course exceptions, but the experience is quite general and most operating companies anticipate breakdown by periodic tests designed to weed out faulty units.

The apparent deterioration of porcelain is generally due to one of the following causes:

1. Gradual mechanical cracking, due to expansion of cement or tight-fitting metal parts, or to internal firing strains or brittle porcelain.

2. Gradual absorption of moisture due to porosity.

The greater part of the trouble has been due to cracking under stresses caused by expansion of cement or of tight-fitting or cemented-in metal parts. Cracking may also be caused by uneven expansion in very thick porcelain parts of different shapes.

The foregoing causes of deterioration are well verified in practise, because the type of insulator in which the porcelain units are strung together by loose fitting metal parts or cables shows no deterioration after ten years or more of service. This was found to be so even when some of the earlier units were made of poor material. The absorption of moisture seems to be due to a considerable extent to breathing. The presence of a damp sponge of cement is thus also undesirable from this standpoint as it keeps moist the air breathed by the porcelain.

The solution of the deterioration problem seems to be to start with a design as free as possible from expansion troubles and the selection of a tough, non-porous porcelain. Years of service have been the best criterion of design. Regarding the selection of material, no present, practical electrical test will anticipate future cracking due to internal strains or brittle porcelain or will indicate porosity in dry porcelain. The desired results can probably best be attained by testing a small percentage of the product to destruction from day to day after the usual electrical and inspection tests have been made, the object being to determine if the product is up to the standard and of uniform quality. This idea is not new, but is used in the manufacture of lamps and in other industries. Electrical, mechanical and porosity uniformity tests are necessary. Extremely accurate tests are not necessary, but it is necessary to have tests that can be quickly made so that any fault can be at once detected and remedied.

In our investigation we made first the electrical tests, followed by mechanical impact tests to destruction. Samples were then taken from the head and thick parts of the units and subjected to a porosity test. In this test the samples were placed in a dye solution under pressure, after which the depth of penetration was noted. The porcelain was placed in three arbitrary mechanical and porosity grades and a graphical chart made indicating the percentage in each

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grade as shown in Fig. 1. We found this method of great use not only in checking the product and comparing different materials, but also in studying deterioration of insulators in service.

Insulators for the Higher Voltages

The problem of deterioration discussed above is independent of the voltage. Its effect on operation

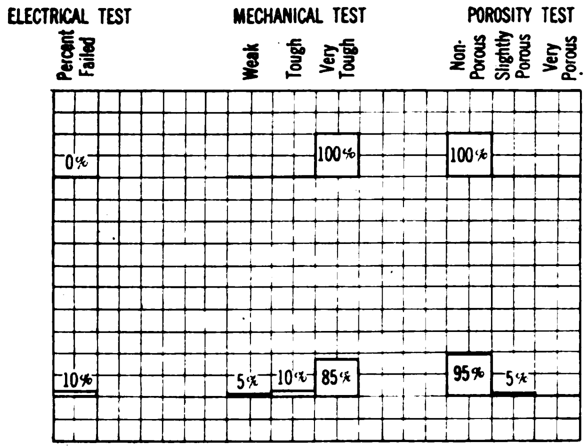


Fig. 1—Sample Sheet Showing Method of Plotting Electrical, Mechanical and Porosity Tests

should be less at the higher voltages because of the greater number of units used in a string. There are, however, certain factors unimportant at the lower voltages, which become of increasing importance as the voltage is increased.

Uneven Voltage Distribution. It has long been known that when insulators are placed in series in a string the

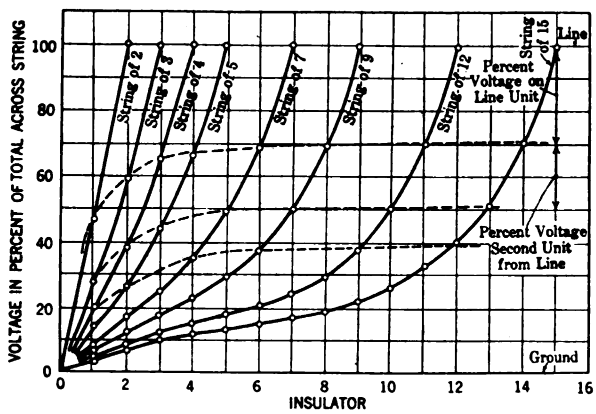


Fig. 2—Typical Voltage Distribution Curves on Strings of Suspension Insulators

arc-over voltage is not the sum of the arc-over voltages of the individual units, but less. This is due to the uneven division of voltage on the different units. A very high percentage is across the unit nearest the line. Typical curves are given in Fig. 2. Fig. 3 shows the percentage of the total voltage across each unit of a string of ten. Even distribution would put 10 per cent on each unit as indicated by the dotted line. It will be noted on examination of Fig. 2 that for strings over five units in length, there is always about 30 per cent of the total voltage across the insulator nearest the line. This will vary from 20 to 30 per cent with different types of insulators and with different hardware on the same type. The importance of a consideration of this

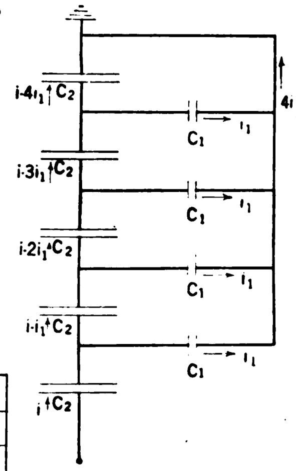


Fig. 4—Cause of Uneven Distribution
The capacities to ground C_1 cause an uneven distribution of current through the insulator capacity C_2.

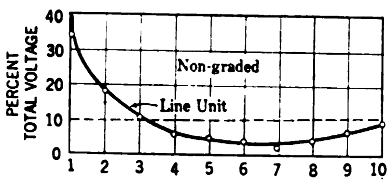


Fig. 3—Voltage Distribution on String of Ten Insulators

factor at the higher voltage is at once seen since the maximum unit stress increases directly with the voltage. At 100 kv. the operating stress on the line unit is 17.4 kv.; at 220 kv. it is 38 kv., which is higher than is desirable.[1] It is desirable to lower the operating stress on the units near the line.

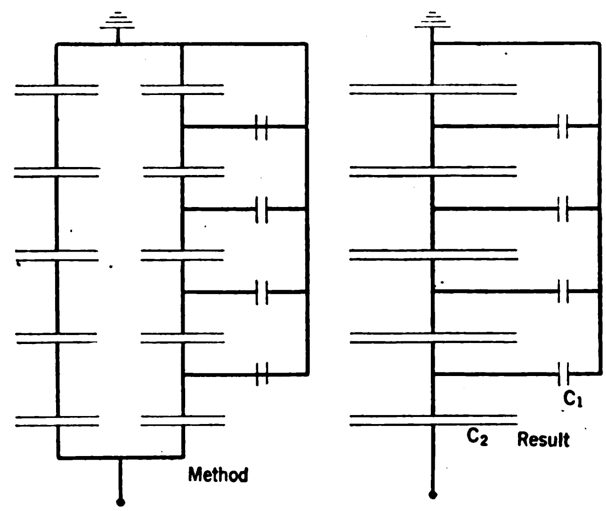


Fig. 5—Grading by Making Internal Capacity of Insulator Units C_2 Large Compared to the Capacity to Ground C_1.

A mathematical analysis of the cause of uneven distribution has already been given.[2] It seems best,

1. $\frac{220}{\sqrt{3}} \times 0.30 = 38$. In the case of a grounded line on a system with isolated neutral this voltage would be $220 \times 0.30 = 66$ kv.

2. Peek, "Electrical Characteristics of the Suspension Insulator—I," A. I. E. E. Transactions 1912, Vol. XXXI, page 907

however, to give here an elementary review of the causes of uneven distribution in order better to discuss the methods of remedying it.

A string of line insulators may be considered as being made up of a number of capacities in series.

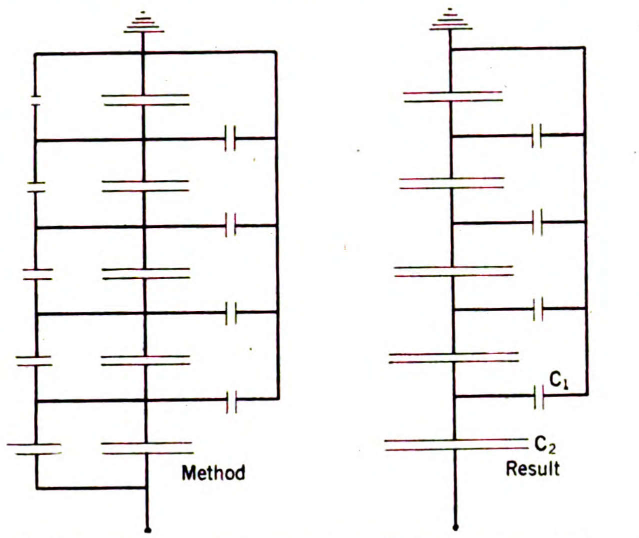


Fig. 6—Grading by Changing the C_2 Capacities in Proportion to Their Respective Currents

There is also capacity from the hardware and fittings of each unit to ground. The capacity may be represented diagramatically by Fig. 4. This arrangement is approximate, but suitable for the purpose of illustration.

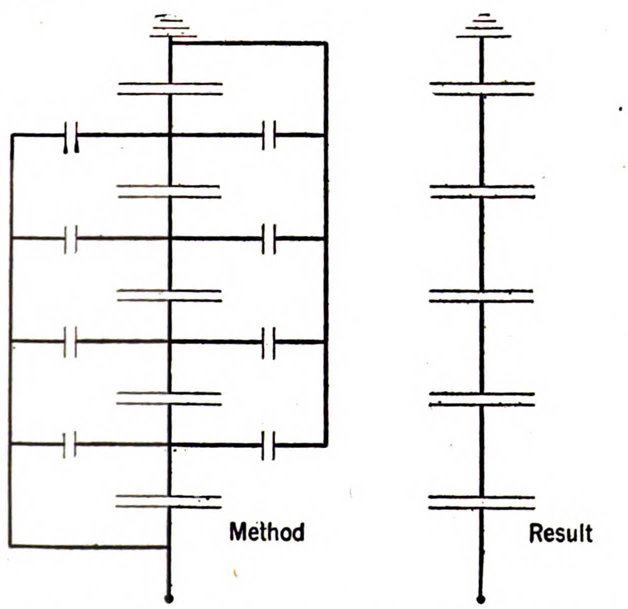


Fig. 7—Grading or Shielding by Eliminating the Effect of the Capacities to Ground

It is at once apparent that the capacity currents cause unequal voltage distribution. If i is the total current through the first insulator, the capacity current through the second one from the line is $i - i_1$ where i_1 is the capacity current to ground; and third from the line $i - 2\,i_1$; the fourth $i - 3\,i_1$, etc. The current and, therefore, the drop is greatest on the line unit; the current decreases successively on each unit from the line by the current to ground of one unit. Correction of voltage distribution may be made by eliminating

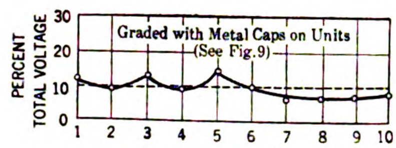


Fig. 8—Voltage Distribution on String of Ten Insulators

the effect of the ground current or the capacities to ground, C_1.

This may be done by any one of the following methods:

1. Increasing all of the C_2 capacities without increasing the C_1 capacities so that the effect of the current to ground is relatively less. See Fig. 5.

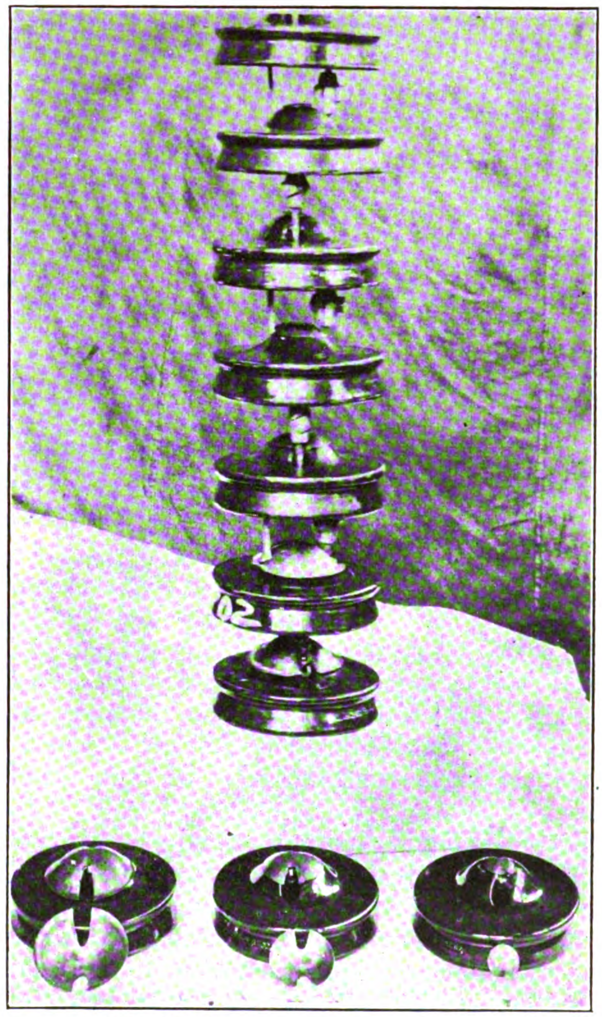


Fig. 9—Grading by Metal Caps

2. Increasing the C_2 capacities of the insulators along the string in proportion to the currents flowing through them. This means highest C_2 capacity on the

line unit, less on the next unit, etc. See Fig. 6—This is generally called grading.

3. Elimination of the ground capacities by means of an antenna shield from the line. See Fig. 7. This may be called shielding.

In order to get appreciable results by method 1, it is necessary to add capacities with solid insulation, or plates in intimate contact with the porcelain. Plates along the string will not help materially, as the percentage increase in the C_2 capacities will generally be smaller than the percentage increase in the C_1 capacities.

Method 2 is practical but it must be accomplished by adding capacities with solid insulations. In practise it means the addition of metal caps or plates in intimate contact with the units, or varying the wall thickness of units, or placing a varying number of units in multiple along the string, or using different sizes of units. Very good results can be obtained by

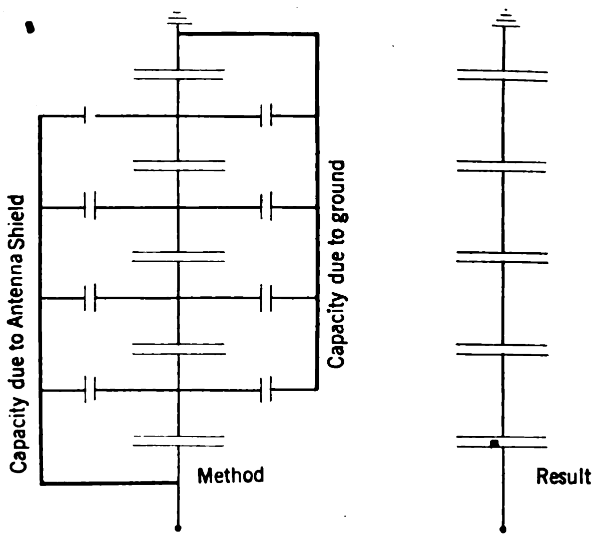


Fig. 10—Shielding by Eliminating the Effect of the Capacity to Ground

this method. Its undesirable feature is that it requires different kinds or sizes of units in the same string. Figs. 8 and 9 show the voltage distribution in a string graded by placing different sizes of caps along the string.

Very good voltage distribution can be easily obtained by method 3. The ground capacities may be thought of as being due to grounded antenna extending along the string. The effect of this antenna may be eliminated by a similar antenna connected to the line and extending along the string as in Fig. 10. In practise the antenna is the very simple shield shown in Fig. 11. The hardware shown in Fig. 11 is not standard but was selected for laboratory purposes to give the worst distribution. The shield readily corrects it. The maximum unit stress would be less on a 220-kv. shielded string than on present non-shielded strings operating sucessfully at 100 kv. and less. The distribution with and without the shield is shown in Fig. 12. A standard hardware giving better distribution with and without the shield is shown in Fig. 13.

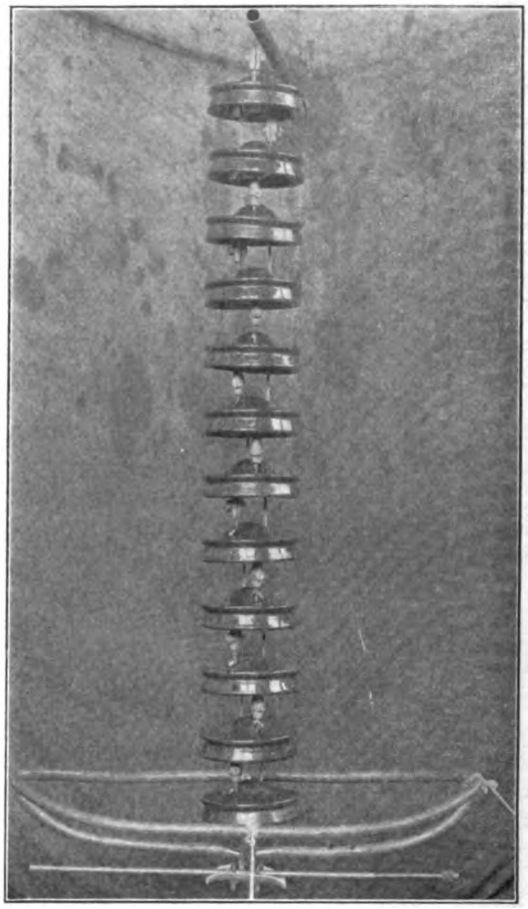


Fig. 11—Antenna Shield for Equalizing Voltage on Insulators
(Laboratory hardware)

This method requires no special units. The antenna has an additional advantage of acting as a corona shield, eliminating corona from the string and tending

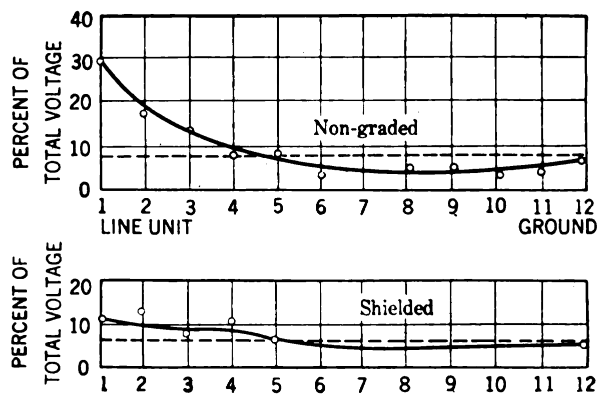


Fig. 12—Voltage Distribution on a String of Twelve Insulators
(See Fig. 11—Laboratory hardware.)

to keep the power arc from the insulators and from burning the conductors. Even if the voltage were evenly distributed a corona eliminating shield would be advisable at the higher voltages.

Heretofore the main argument given for equalizing voltage distribution has been to reduce the string length by increasing the arc-over voltage for a given number of units. It is much more important to reduce the operating stress on the line-end units.

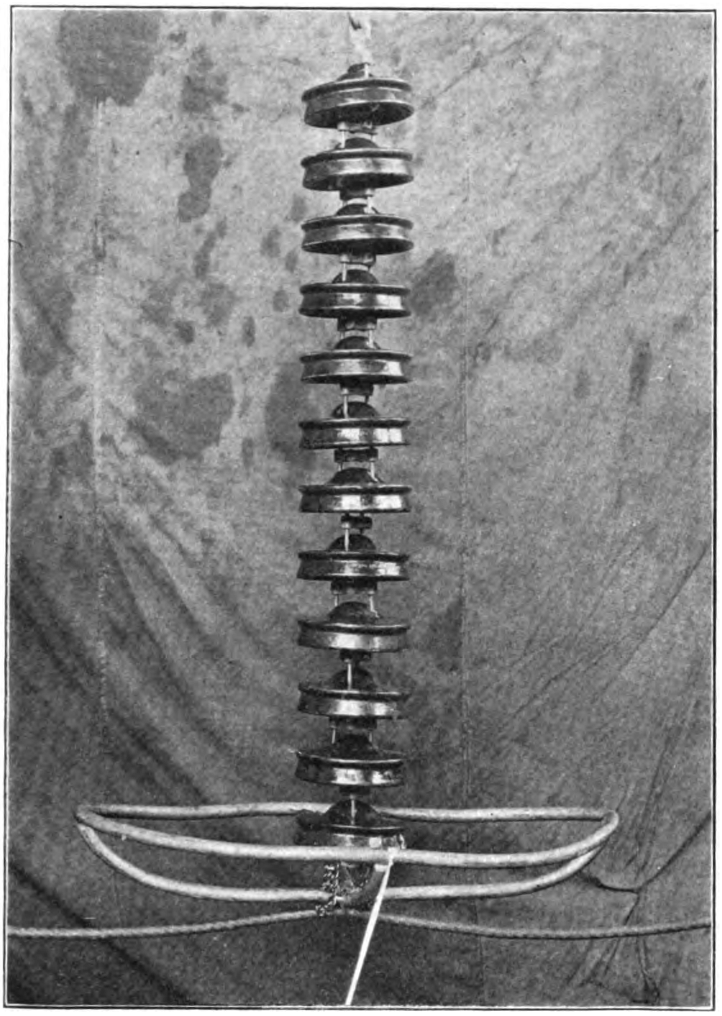


Fig. 13—Antenna Shield
Insulators strung with standard hardware.

With certain types of units the wet arc-over voltage may be higher than the dry arc-over voltage for long strings.[3] This is because rain may assist in grading a badly unbalanced string. As a general rule, a string cannot be very greatly shortened in practise by grading because of the effects of rain, dirt, etc. on the perfectly graded string. There would be little gain in increasing the dry arc-over voltage if the wet arc-over voltage were decreased. Rain would not increase the wet arc-over voltage of a graded string. The wet arc-over voltage would generally be lower if the string length were decreased.

There is an additional reason why grading will generally not make possible an increase in the arc-over voltage or a decrease in the string length. For any unbalanced string there is more or less complete automatic grading as the arc-over voltage is approached. Near arc-over excessive corona forms on the line unit, to a less extent on the next unit, etc. These sheets of corona act as capacity plates and grade the string, thus automatically raising the arc-over voltage. If this were not so, it would be expected that the arc-over voltage for the non-graded string above could for five or more units, never be higher than $\frac{1}{0.30} = 3.3$ times the arc-over voltage of a single unit. As a matter of fact, it is much higher, due to the automatic grading of corona.

The wet and dry arc-over voltage of insulators decreases almost directly with barometric pressure.

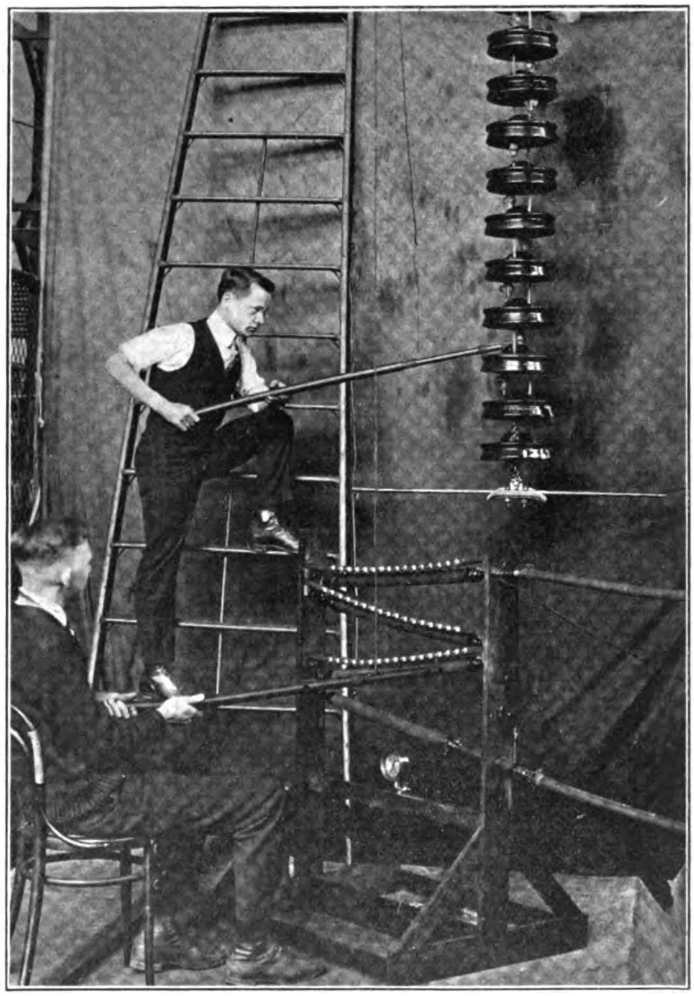


Fig. 14—Method of Making Distribution Measurements

The insulator problem for the higher voltages is therefore more difficult at higher altitudes.

It has been found that the wet lightning arc-over voltage is usually as high as the dry lightning arc-over voltage.[4] The lightning arc-over voltage is, to a great

3. Peek, "Electrical Characteristics of the Suspension Insulator—I." A. I. E. E. Transactions 1912. Vol. XXXI, page 907.

4. Peek, "The Effect of Transient Voltages on Dielectrics," A. I. E. E. Transactions, 1915, vol. XXXLV, page 1857.

extent, a question of string length. If the string length is decreased due to grading the lightning arc-over voltage will also be decreased.

Tests

It may be of interest to describe the method of making tests. A water resistance with 50 taps was

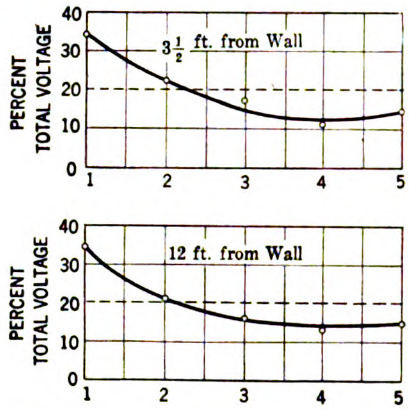


Fig. 15—The Effect of Proximity to Walls
Voltage Distribution on String of Five Insulators.

placed across the line in parallel with the insulators as shown in the illustration, Fig. 14. Each tap had a fixed and known potential above ground, *i. e.*, a given percentage of the applied voltage. Connection was made between the particular unit, the potential of which was being investigated and various taps on the resistance until a tap was found of the same potential. In making this measurement a wire was fastened to a

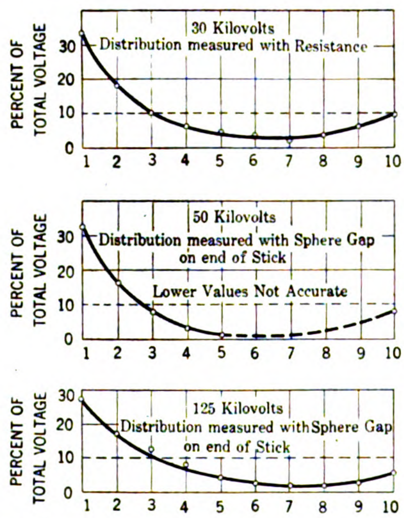


Fig. 16—The Effect of Applied Voltage on the Distribution of a String of Ten

tap and the other end of the wire fastened to a steel point at the end of a fibre rod. When the rod was brought up to the cap a spark would indicate a difference of potential. The connection on the tap was then changed, or the operation was repeated until no spark occurred when the point touched the insulator cap. It was found that the steel point, because of the color of the spark, indicated the smallest difference of potential. In making measurements it is necessary to prevent as far as possible any distortion of the field by the wire and point. A distortion is indicated by different potential readings when measurements are made at

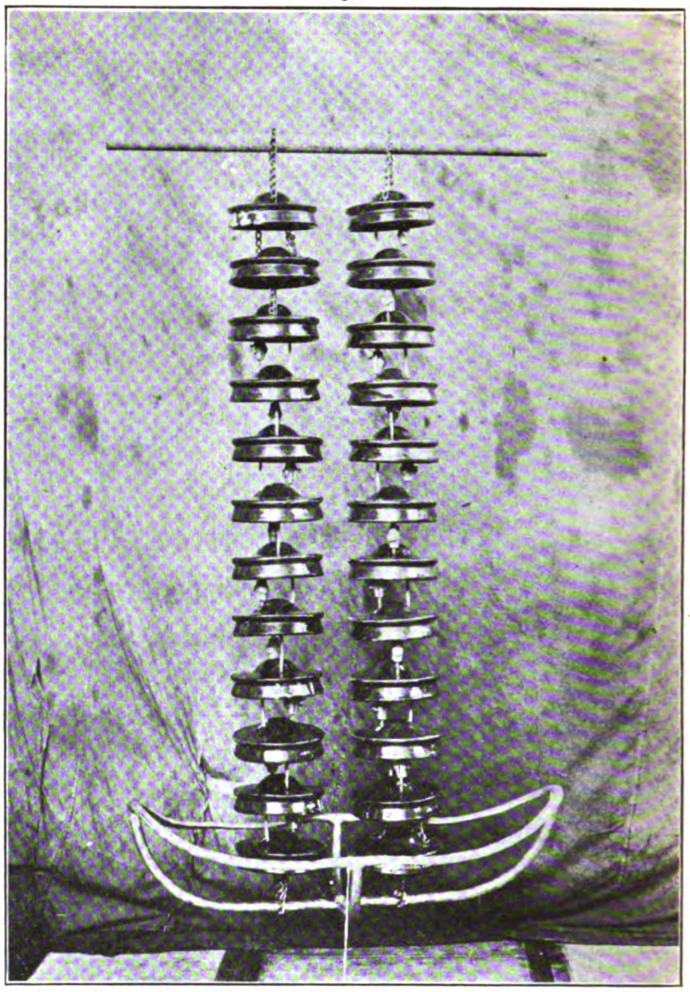


Fig. 17—Antenna Shield on a Double String
Laboratory hardware—See Fig. 18.

different points around the insulator. A stream of water was kept running through the tube in order to keep the temperature constant. Approximate potential read-

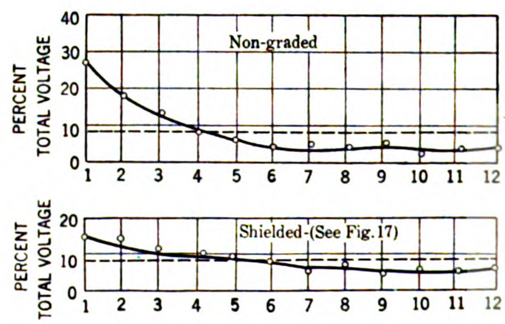


Fig. 18—Voltage Distribution on Two Parallel Strings of Twelve Insulators

ings can be obtained by placing a very small gap shunting a forked stick across the units. This method gives fairly accurate results on the two or three units near the line, but quite inaccurate results on the others.

The effect of proximity to tower, etc., is given in Fig. 15. It will be seen that it is not great. The effect of corona on distribution is not great at the operating voltage. For instance there is very little

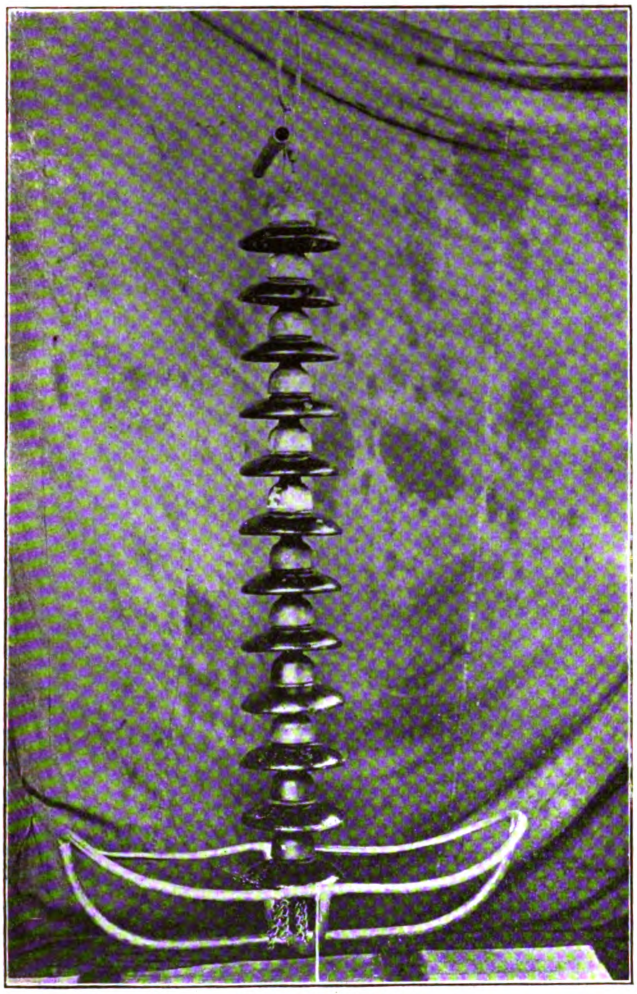


Fig. 19—Antenna Shield
(See Fig. 20.)

difference in the voltage distribution between 30 and 130 kv. 130 kv. is approximately the voltage to neutral of a 220-kv. system. Fig. 16 shows the distribution at 30, 50 and 125 kv. The 50 and 125-kv. curves were made with a spark gap and are accurate for the three units near the line only. Fig. 17 shows the shield used on a double string. The distribution is very good as shown in Fig. 18.

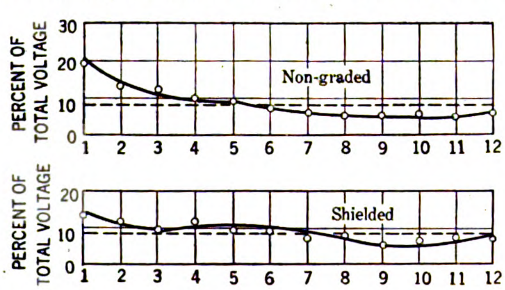


Fig. 20—Voltage Distribution on String of Twelve Insulators
(See Fig. 19.)

Figs. 19 and 20 show the shield and distribution on other types of units. A corona shield is also desirable on this type at 220 kv. The effect on voltage distribution of placing a shielded string in a horizontal position was investigated and found to be negligible. See Fig. 21.

The method of grading shown in Fig. 22 was not found to be very satisfactory.

Fig. 23 shows a form of shield that gave fairly good results.

Distribution tests were made to see if there would be

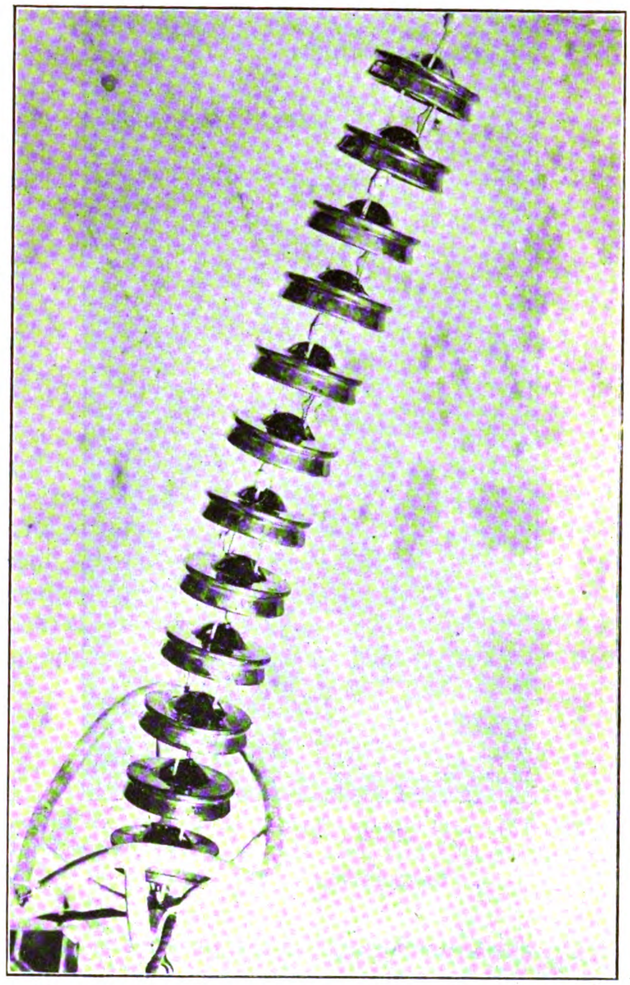


Fig. 21—Antenna Shield for Equalizing Voltage on Insulators

any disturbing effect due to the proximity of other insulator strings as in operation on a three-phase line. There was found to be no appreciable effect.

It is not possible to show all of the various shields tried, but it is believed that the above fairly well covers the field.

Summary

From the above discussion it may be concluded that:

Insulator troubles have been due mainly to cracking caused by expansion of metal parts, cement, etc. and to porosity.

Certain designs with loose-fitting parts have been

free from deterioration. Other designs should be so modified as to relieve them as far as possible from expansion troubles.

Tough non-porous porcelain is desirable.

The old method of basing everything on electrical tests should be abandoned. Severe electrical tests are often harmful. The electrical strength is often secondary to other characteristics. An electrical, mechanical and porosity uniformity test should be established, in which a small percentage of the product is tested to destruction from day to day to ascertain if it is running brittle or porous or is weakened by firing strains.

For the very high voltages that are at present being considered, greater reliability may in many respects be anticipated than for the lower voltage lines. The lightning arc-over voltage and dielectric strength will be relatively higher and induced lightning voltages, sufficient to cause arc-over, will be less than on low-voltage lines. Increasing the number of units in series decreases the probability of complete string failure.

Uneven distribution of voltage on the string becomes more serious at the higher voltages because of the high stress on the unit near the line. For strings of more than four or five units the stress is practically a constant percentage of the operating voltage independent of the string length.

Uneven distribution can be corrected by shielding, shielding prevents excessive corona on the line end units and tends to direct the power arc away from the string. The maximum unit stress on a 220-kv. shield string can be made less than on a 100-kv. non-shielded string.

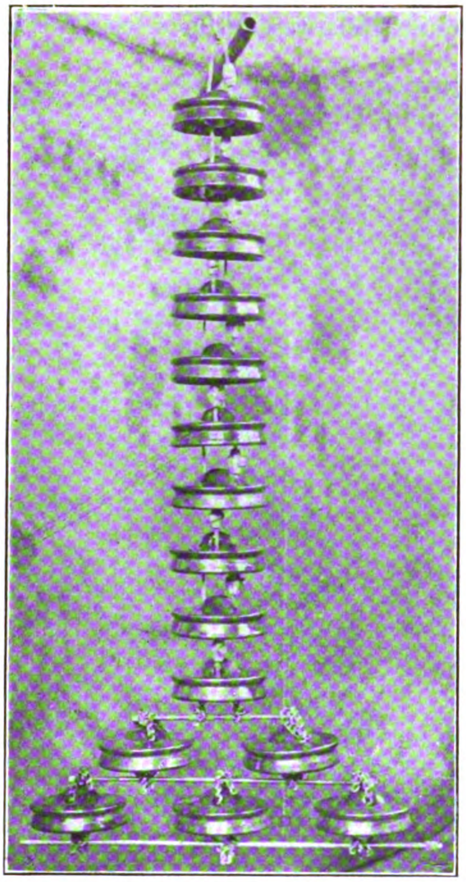


Fig. 22—Two and Three Units in Parallel at Line End of String of 12 Units as a Means of Improving Voltage Distribution on the String

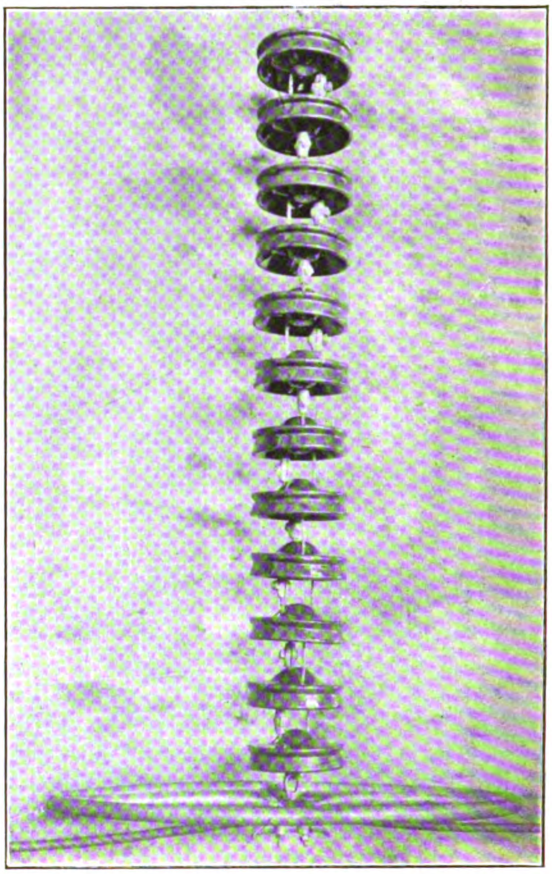


Fig. 23—Antenna Shield for Equalizing Voltage on Insulators

Briefly, outages due to insulator troubles will probably be less frequent at the higher voltages than at present.

The author acknowledges the assistance of Mr. W. L. Lloyd, Jr. in making this investigation.

Unit Voltage Duties in Long Suspension Insulators

BY HARRIS J. RYAN and HENRY H. HENLINE

Both of Leland Stanford Jr. University

POTENTIOMETER measurements* were made of the maximum and average voltage duties occurring in strings made up of *10-inch cap and pin type units* wherein the numbers of the units were varied from 2 to 20. The numbers of units in the string and their corresponding maximum to average voltage duty-ratios thus obtained were used to locate curve II in Fig. 1. The increase in the duty-ratios is small for the shortest string of two units, it accelerates rapidly as the string is lengthened to 7 units and thereafter it remains constant at the rate of 0.09 per unit added from 7 to 20. Such increase is low and accelerating in *short strings* of from 2 to 7 units while it is high and constant in *long strings* of 7 or more units.

In a string of 10-inch *bomb and link type units* the maximum to average voltage unit duty-ratio was found to be 2.5 thus locating approximately the steeper broken line curve I, Fig. 1.

The relation between the unit maximum voltage

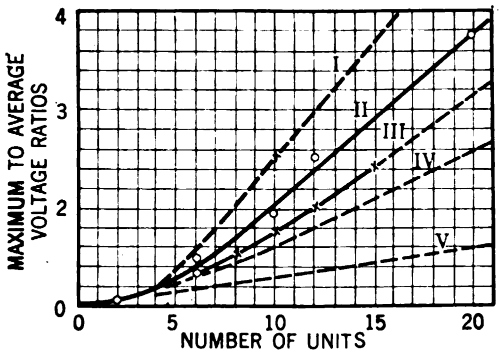


FIG. 1

duty, number of units in the string and three-phase line voltage is given by the equation

$$e_{md} = \frac{d\ e}{1.73\,n}$$

wherein e = three-phase line voltage
e_{md} = maximum voltage unit duty
n = number of units in string
d_r = corresponding duty-ratio taken from sources in Fig. 2.

By means of this equation using values of d_r from curve II, Fig. 1, the maximum voltage unit-duties for corresponding numbers of cap and pin units in the string were determined for line voltages of 110, 150, 175 and 220 kilovolts and employed to locate curves I, II, III, and IV in Fig. 2. Again by using values of d_r for bomb and link units from curve I, Fig. 1, for a line voltage of 150 kilovolts, curve V, Fig. 2, was located.

An inspection of these curves reveals the fact that when the maximum and average voltage unit-duties are assumed to be limited to 18 and 10 kilovolts respectively for cap and pin type units the upper limit of line voltage will be 150 kilovolts and the length

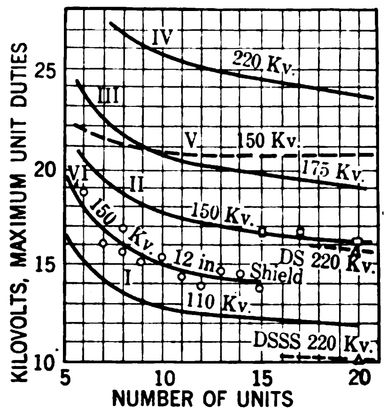


FIG 2

of the string will correspondingly be 9 units. Increasing the number of units from 9 to 20 at this fixed line voltage would lower the maximum voltage unit-duty from 18 to 16 kilovolts, only, permitting a corresponding rise of line voltage in the proportion of 16 to 18, *i. e.*, 11 per cent, or from 150 to 165 kilovolts, an amount that would hardly pay in whole or in part.

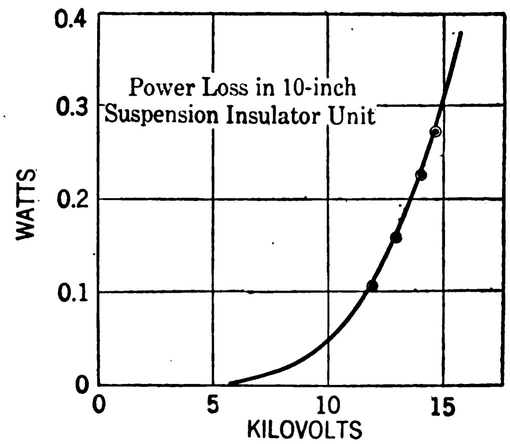


FIG. 3

For a nine-unit string of bomb and link units supporting a 150-kilovolt line the maximum and average voltage unit-duties as obtained from curve V, Fig. 2, are 20.9 and 9.6 kilovolts respectively. While these values are probably permissible, judgment in regard hereto does not appear to be as well defined as for the corresponding values of 18 and 10 assumed for the cap and pin type units.

To be presented at the Pacific Coast Convention, A. I. E. E., Portland, Ore., July 21-23, 1920.

*The High-Voltage Potentiometer by Harris J. Ryan. TRANS. A. I. E. E. Vol. 35, p. 1131, 1916.

The curves reveal further that an increase in string length from 10 to 20 units will cause a corresponding increase in steep wave front flash-over voltage of about 9 per cent for the cap and pin type units and no increase whatever for units of the lower capacitance.

When used to support and insulate a 220-kilovolt line a 13-unit cap and pin string would operate at maximum and average unit voltage duties of 25 and 10 kilovolts respectively. The arrival of loss and corona formation with increase in voltage duty sustained by a 10-inch cap and pin type unit may be noted in the watts-lost-kilovolts curve in Fig. 3. Many engineers feel that a duty of 25 kilovolts for a single 10-inch cap and pin type unit is too high because of corona formation and the injury to hardware and porcelain that may result, likewise because of the low factor of safety against flash-over by cascading. This latter factor is the cause that eliminates the value of a radical departure in the design and construction of the units whereby they would endure satisfactorily much higher maximum voltages. Such practise would tend to increase unduly the maximum to average duty-ratio resulting in low flash-over values. It is generally conceded, therefore, that in the present state of the art some additional means must be employed in suspension insulators for the 220- or 250-kilovolts lines whereby the maximum unit-duties will not be excessive compared with those of present practise.

These maximum unit-duties may be lowered by one or more of the following expedients:

I. Increase in size and capacitance of some or all of the units; grading.

II. Increase in the number of strings in the insulators.

III. Use of static shields.

The first of these, *i. e.*, larger units and grading, is regarded primarily as a manufacturer's problem and will not be taken up in the present paper.

As to what may be accomplished by means of the second and third of these expediencies the following is an illustration: The reductions in maximum unit voltage duty produced in a 20-unit, 10-inch cap and pin type, insulator, (1) by using two strings and (2) by adding static shields made of 2.5 inch well casing 4 feet in diameter, were observed in 1917 by Dr. Leonard F. Fuller and one of the authors in the development of an insulator for the temporary support of a heavy radio aerial operated at 100 undamped wave kilovolts to ground. The results obtained are targeted correspondingly for the 220-kilovolt power line in Fig. 2. The maximum unit voltage duty for the single string was found to be 23.5, for the double string, 15.5 and for the double string with static shields, 10 kilovolts.

Another set of measurements was made by the authors for the specific purpose of illustrating the effect that the use of a small static disk shield would have upon the maximum voltage unit-duty in a single string of cap and pin type units. A dimensioned sketch of the shield used in this case is given in Fig. 4. It is 12 inches in diameter and was developed by Mr. John A. Koontz. A single twenty-unit string without the shield was first set up and the maximum voltage duty carried by the end unit adjacent to the line conductor was determined. The string was then shortened first to 17, and then to 15 units and the corresponding maximum voltage unit-duties also determined. The values thereby obtained were targeted with little squares for a line voltage of 150 kilovolts in Fig. 2, and the values were found to be in agreement with the corresponding values in curve II as calculated from curve II, Fig.1.

The static shield was then mounted and as the string was further shortened, one unit at a time, the corresponding maximum voltage unit-duties were again observed and marked with small circles to locate curve VI, Fig. 2. The same set of values were used to locate the maximum-to-average voltage unit-duty ratio curve III, Fig. 1. For the string of 10 units supporting the 150-kilovolt line, the effect of the presence of this static shield was to lower the maximum voltage unit-duty from 17.5 to 15.0 kilovolts. This corresponds to an allowable upper limit of line voltage

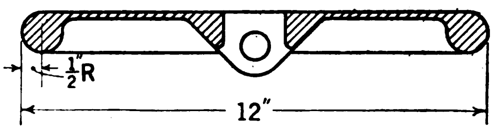


Fig. 4

of $150 \times 17.5 \div 15 = 175$ kilovolts. The essential values for such higher voltage would stand as follows:

No. of units in string,	ten with 12-in. shield.
Line Voltage,	175 kilovolts
Voltage to neutral	101 "
Average voltage unit-duty,	10.1 "
Maximum " "	17.5 "

The corresponding values for the nine-unit insulator without static shield supporting the 150 kilovolt line are:

No. of units in string,	nine without shield.
Line Voltage,	150 kilovolts
Voltage to neutral,	86.6 "
Average voltage unit-duty,	9.6 "
Maximum " " "	18. "

It follows that the *ten* 10-inch cap and pin unit suspension insulator equipped with the 12-inch static shield should serve as satisfactorily for the insulation of the 175-kilovolt line as the corresponding *nine*-unit insulator without shield now serves to insulate the 150-kilovolt line.

From these two illustrations it is seen that by the practicable expediency of increasing the capacitance of the units, of increasing the number of strings of units or of using static shields or by a combination thereof, the maximum voltage unit-duty may be lowered in the long strings (15 units) from 30 to 11 kilovolts for a corresponding average voltage unit-duty of 10

kilovolts. Or more technically, the rate of increase of maximum to average voltage unit-duty ratio with unit increase of string-length can be decreased in long strings by such expedients from 0.2 to 0.02.

Many physical, economic and practical factors enter into the general problem of the extra high-voltage line insulator, *first* as to the make-up and service character of the single unit apart from the insulator as a whole and *second* with respect to the number of units in the insulator string, the number of strings and the form and size of the static shields to be employed. The present units in use are due to a highly organized and experienced cooperation of ceramic, structural and electrical engineers. The integrity of the individual units is a matter of the utmost importance for which, because of the nature of things, the manufacturer must assume responsibility. Not until the manufacturer has amply demonstrated his immediate readiness to deliver by economic quantity production, durable units in which radical changes have been made in design, size and rated mechanical and electrical duty, can the transmission engineer count upon the use of units that may thus differ materially from those in use at present for the support of extra high-voltage (220 kv.) power lines. Such lines will constitute channels through which enormous powers will flow for maintaining the vital industries of regions that are state wide. Avoidable interruptions cannot be tolerated. Uncertain factors in the reliability of these super-power lines will have to be reduced to a minimum. It has taken years to develop for economic quantity production the excellent ten-inch units that are now in extensive and dependable use. Unless the manufacturer can make an ample showing that he is ready to deliver in quantity, designs for extra high-voltage line insulators that have an aggregate superiority in essential qualities, *i. e.* form, durability and cost, the transmission engineer will assuredly undertake the insulation of the extra high-voltage lines with the present units because he knows the essential limits within which he can depend upon them.

The electrical factors in the extra high-voltage insulator that concern the transmission engineer eventually reduce to three fundamentals, viz.: (1) type of unit, (2) maximum and (3) average voltage unit-duties.

The determination of these must rest upon a capable and experienced judgment for any particular requirement. It is the purpose of the authors to deal, only with the quantitative relations that exist between the second and third of such fundamentals, viz.: *the maximum and average voltage unit-duties in line suspension insulators made up of units in common use,* to constitute an aid to the judgment for those who must decide upon the make-up of the insulators to be used for the extra high-voltage lines for which they will be responsible. As yet reliable, analytical methods have not been found for the determination of these maximum to average unit-duty relations when two or more strings and static shields are involved. The relations can only be determined by measurements. Such measurements must be undertaken indoors. It is work that requires large open spaces that are ordinarily difficult to provide. At no time in the present work did the authors have at their disposal as large a space as desired in order to be assured that the presence of walls or nearby laboratory equipment would not affect the value of the results. It was necessary, therefore, to test the integrity of the results by such means as were at hand. In so doing measurements were repeated with the insulators and their high-

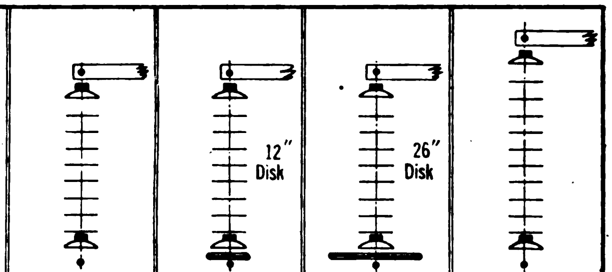


	Fig. 5		Fig. 6		Fig. 7		Fig. 8	
Strings	Single 10		Single 10		Single 10		Single 12	
Line Kv.	173		173		173		208	
Kv. to Neut.	100		100		100		120	
Unit No.	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total
1	19.4	19.4	15.8	15.8	11.8	11.8	25.0	20.8
2	15.6	15.6	14.2	14.2	12.4	12.4	18.0	15.0
3	11.9	11.9	12.5	12.5	11.0	11.0	14.0	11.7
4	10.6	10.6	10.3	10.3	10.6	10.6	11.0	9.2
5	8.4	8.4	10.0	10.0	9.9	9.9	8.0	6.7
6	5.5	5.5	6.8	6.8	9.0	9.0	7.5	6.2
7	8.0	8.0	7.0	7.0	8.4	8.4	7.0	5.8
8	6.8	6.8	7.6	7.6	8.8	8.8	6.0	5.0
9	5.9	5.9	8.4	8.4	8.5	8.5	6.0	5.0
10	7.9	7.9	7.4	7.4	9.6	9.6	6.0	5.0
11							6.0	5.0
12							5.5	4.6

Figs. 5—6—7—8

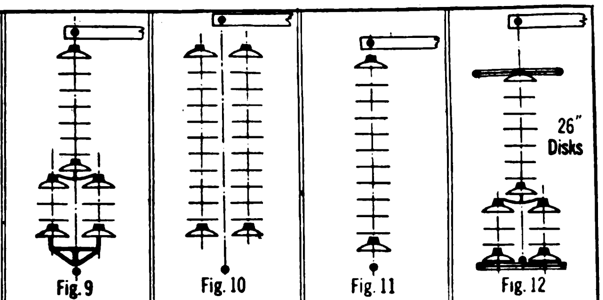
voltage line conductors inverted in position with respect to the ground and the potentiometer; by moving them away from nearby walls and model of tower to a position of greater elevation and isolation in the center of the building. When substantially the same results were obtained for all such positions as specified it was concluded that the nearby walls and low elevation of the insulator and high-voltage conductor did not produce results essentially different from those that would be obtained when the insulators would be mounted in the open from regular tower cross-arms.

The results obtained are expressed in the series of Figs. 5 to 21 and the accompanying tables. In the figures, sketches approximately to scale are given of the forms of long insulators of single and double strings with or without static shields. In the tables found below each insulator sketch, the values of the voltage duties are given that are carried by the corresponding units in the string. Such values throughout for all of these cases have been adjusted to a uniform average

unit-duty of 10 kilovolts. The actual voltages applied to the insulators when the measurements were made were always near to the value

$$\text{Kilovolts} = 10n$$

wherein n is the number of units in the insulator string. Thus one may note in the tables the ratios of any actual to average unit voltage duties by dividing the duty as given by 10. For the aid of those who are accustomed to think of the unit-duties in percentages of total applied voltages, parallel columns have been inserted in the tables giving such percentages. It is assumed that these sketches and tables are for the rest self-explanatory and that little further narative in regard to them is necessary.

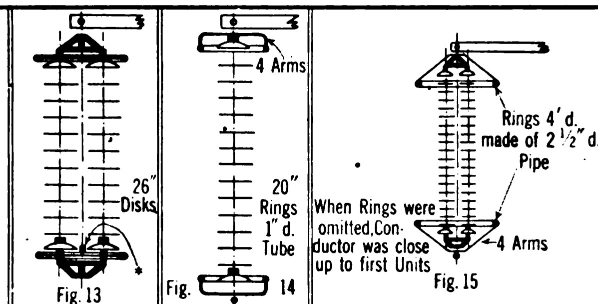


Strings	Single-Double-12		Double-12		Single-12		Single-Double-12	
Line Kv.	208		208		208		208	
Kv. to Neut.	120		120		120		120	
Unit No.	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total
1	22.9	19.1	22.7	18.9	17.0	14.2	14.3	11.9
2	15.4	12.8	18.3	15.2	15.8	13.2	13.1	10.9
3	12.6	10.5	13.1	10.9	14.3	11.9	11.5	9.6
4	8.7	7.3	9.9	8.3	11.7	9.8	10.1	8.4
5	10.5	8.8	8.5	7.1	10.3	8.8	9.6	8.0
6	8.8	7.3	7.7	6.4	8.7	7.2	11.2	9.3
7	7.7	6.4	7.0	5.8	7.6	6.3	9.5	7.9
8	7.0	5.8	6.8	5.7	7.3	6.1	8.8	7.3
9	6.5	5.4	6.6	5.5	7.1	5.8	8.4	7.0
10	6.6	5.5	6.5	5.4	6.8	5.7	8.0	6.7
11	6.5	5.4	6.3	5.3	6.7	5.6	7.5	6.3
12	6.8	5.7	6.6	5.5	6.7	5.6	8.0	6.7

Figs. 9—10—11—12

From the upper end of the insulator under test metal tubes were mounted horizontally and vertically to the floor so as to affect the electric field about the insulator in the manner that would be done by the upper portion of a particular tower with its cross-arm that will be used in a new project for the support of a 150-kilovolt power line. The upper or cross-arm end of the unit was fixed at about 16 feet from the concrete floor and the vertical central axis of the insulator was about eight feet from the dry brick wall of the laboratory. Exceptions hereto occurred when the insulator was inverted or removed to the center of the laboratory for checking purposes. In the latter case the 20-foot, 1-inch line conductor, maker's standard line clamp and first unit were mounted approximately 16 feet from the floor while the upper grounded end-unit was higher by the length of the string, *i. e.* at a height of from 20 to 25 feet while the central axis of the insulator was remote from the vertical grounding wire about 10 feet and the nearest brick wall about 15 feet. Exception likewise occurred in the single case of the insulator mounted with jumper for strain duty. The strain insulator, one-inch diameter aluminum cable conductor and jumper were mounted in the vertical. The lower end unit was approximately eight feet from the ground. It is believed, however, that the results obtained are near to those that would be obtained correspondingly under actual service conditions.

Unit voltage duty measurements were made with and without a single, circular, 26-inch diameter static shield mounted between the line conductor and the first unit. The results obtained are given in the tables below Fig. 16 which illustrates this laboratory set-up for the study of a long strain insulator with line jumper. From them the lesson is drawn that the jumper is effective in lowering the maximum unit voltage duty thereby offsetting the rise in such duty produced by mounting the line conductor in the axis of the insulator instead of at right angles thereto; and the further lesson that with the aid of a static shield the strain insulator can be adapted for extra high-voltage duty just about as readily as the suspension insulator.



Strings	Double-12		Single-15		Double-20			
Line Kv.	208		260		346			
Kv. to Neut.	120		150		200			
					WITHOUT SHIELDS		WITH SHIELDS	
Unit No.	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total
1	15.3	12.7	19.9	13.3	24.5	12.2	15.8	7.9
2	14.3	11.9	20.6	13.7	20.5	10.3	15.2	7.6
3	12.7	10.6	15.0	10.0	16.0	8.0	14.4	7.2
4	10.8	9.0	14.3	9.5	14.3	7.2	13.8	6.9
5	9.4	7.8	12.7	8.5	12.2	6.1	12.8	6.4
6	Not	Observed	10.3	6.9	9.8	4.9	11.4	5.7
7	Not	Observed	8.9	5.9	8.0	4.0	10.4	5.2
8	Not	Observed	7.5	5.0	7.5	3.7	9.6	4.8
9	Not	Observed	6.9	4.6	7.7	3.8	9.2	4.6
10	Not	Observed	6.4	4.3	7.5	3.7	9.0	4.5
11	Not	Observed	5.9	3.9	6.7	3.4	8.6	4.3
12	Not	Observed	5.7	3.8	6.5	3.2	8.0	4.3
13			5.5	3.7	6.7	3.4	8.4	4.2
14	*	Mounting	5.3	3.5	7.3	3.6	8.4	4.2
15	Conductor	on Yoke	5.1	3.4	6.6	3.3	8.4	4.2
16	below Sh	ield made			6.0	3.0	7.7	3.8
17	no pract	ical differ-			5.8	2.9	7.4	3.7
18	ence				7.2	3.6	7.0	3.5
19					8.8	4.4	7.0	3.5
20					10.5	5.3	6.9	3.5

Figs. 13—14—15

Because of the extra tower clearance required for the long insulators equipped with large guards the idea

naturally developed that perhaps if the "arcing horns" were used and sufficiently extended and maintained in the plane of the conductor they might serve to reduce the maximum unit voltage duties sufficiently without

STRAIN INSULATOR

	Without Static Shield		With Static Shield	
Line Kv.	208		208	
Kv. to Neutral	120		120	
Unit No.	UNIT DUTY Percent of Total Voltage	Kv.	UNIT DUTY Percent of Total Voltage	Kv.
1	16.	19.2	9.5	11.4
2	13.	15.6	9.5	11.4
3	11.	13.2	9.	10.8
4	9.	10.8	8.25	9.9
5	7.75	9.3	8.	9.6
6	6.75	8.1	7.5	9.
7	6.	7.2	7.5	9.
8	5.5	6.6	7.5	9.
9	5.5	6.6	7.75	9.3
10	5.75	6.9	8.	9.6
11	6.5	7.8	8.25	9.9
12	7.	8.4	9.	10.8

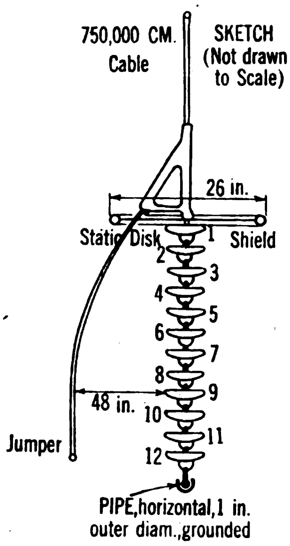
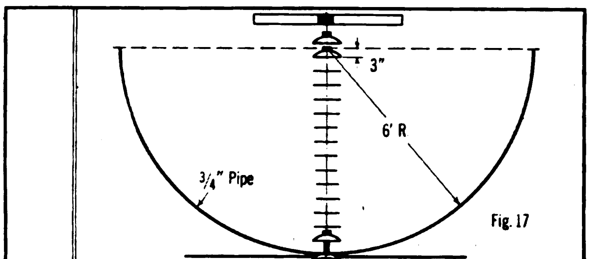


FIG. 16

increasing the necessary tower clearances. Accordingly a cap and pin 15-unit suspension insulator equipped with great arcing horns to function as a static shield was arranged as in Fig. 17 and the unit voltage duties

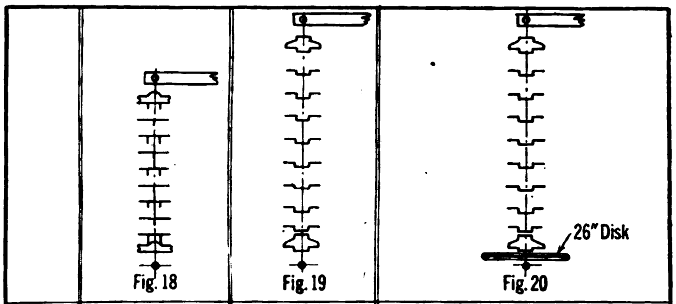


Strings	Single-15	
Line Kv.	206	
Kv. to Neut.	150	
Unit No.	Unit Duty in Kilovolts	Unit Duty Percentage of Total
1	22.5	15.0
2	18.0	12.0
3	14.2	9.5
4	13.5	9.0
5	9.8	6.5
6	8.4	5.6
7	7.8	5.2
8	7.1	4.7
9	6.7	4.5
10	6.5	4.3
11	6.3	4.2
12	6.6	4.4
13	7.1	4.7
14	7.5	5.0
15	8.0	5.4

FIG. 17

and corresponding percentages of line voltage were measured and determined and tabulated below the figure. The results were rather disappointing. They indicate the superiority of the shield which, to save tower clearance when necessary, may be made elliptical as proposed by Mr. Peek.

To aid one's judgment as to the effect of lessened insulator capacitance and of rain upon the values of the unit voltage duties, duty measurements were made upon three long strings of unit-types as follows: *cap and pin, bomb and link and core and tine, all dry, and*



Strings	Single-10		Single-10		Single-10			
Line Kv.	173		173		173			
Kv. to Neut.	100		100		100			
					DRY		WET	
Unit No.	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total	Unit Duty Kv.	Unit Duty Percentage of Total
1	24.8	24.8	31.0	31.0	21.7	21.7	8.4	8.4
2	19.6	19.6	19.2	19.2	17.0	17.0	14.0	14.0
3	12.2	12.2	11.0	11.0	13.2	13.2	13.2	13.2
4	9.7	9.7	8.8	8.8	10.1	10.1	10.1	10.1
5	7.1	7.1	Not	Observed	Not	Observed	Not	Observed
6	4.5	4.5	Not	Observed	Not	Observed	Not	Observed
7	4.0	4.0	Not	Observed	Not	Observed	Not	Observed
8	5.5	5.5	Not	Observed	Not	Observed	Not	Observed
9	6.2	6.2	Not	Observed	Not	Observed	Not	Observed
10	6.4	6.4	Not	Observed	Not	Observed	Not	Observed

FIGS. 18—19—20

core and tine, wet. The results thus obtained are given in the tables below Figs. 18, 19 and 20. The "rain" introduced a strong grading effect, greatly reducing the maximum to average unit voltage duties. Such reduction in this particular case was made to occur from 2.2 to 1.4.

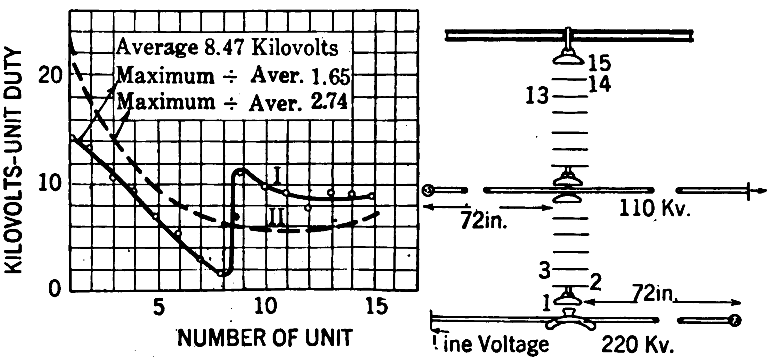


FIG. 21

At the suggestion of one of the engineers who has followed the progress of these studies, the unit voltage duties were determined in an insulator that was subjected to two synchronous in-phase voltages, 63.5 and 127 kilovolts, corresponding to a double line voltage of 110 and 220 kilovolts. The purpose hereof was to obtain knowledge of the corresponding reduction in

unit-duty voltages that result from the use of the associated lines one of which would serve for the flow of trunk line power and the other for power for more local purposes. A single 15-unit cap and pin type string without static shield was arranged to support two 1-inch diameter conductors as illustrated in Fig. 21. The conductor carrying the lower voltage was mounted in the horizontal between the seventh and eighth units. The companion conductor carrying the higher voltage was mounted parallel thereto from the end unit by means of the maker's standard clamp.

With the insulator, conductors and voltages arranged as specified the unit voltages were then measured and the values obtained were used to locate curve 1, Fig. 21. This curve reveals the manner in which the unit voltage duties varied from unit to unit. For comparison the broken-line curve II was located with the corresponding unit voltage duties that were obtained from the same insulator arrangement except that the conductor carrying 110 kilovolts was omitted. It is of interest to note that the ratio of the maximum to average unit-duties was reduced from 2.74 to 1.65 by the presence of the additional conductor carrying one-half main-line voltage.

ACKNOWLEDGMENTS

In closing the authors desire herewith to express their appreciation of the helpful cooperation they have had in the promulgation of these laboratory studies of Messrs. F. G. Baum, S. Barfoed, L. F. Fuller, W. A. Hillebrand, J. P. Jollyman, J. A. Koontz, and J. Mini; for static shields, conductor clamps and other insulator hardware furnished by the Great Western Power Co. and the Pacific Gas and Electric Co.; for insulator units supplied by the Jeffrey-Dewitt Insulator Co., the Ohio Brass Co. and the R. Thomas and Sons Co.; and for assistance in manning the high-voltage potentiometer and preparing figures and tables by F. F. Evenson.

CONCLUSIONS

1. Suspension insulator units in common use can be satisfactorily employed for the make-up of insulators for 250-kilovolt lines.

2. Increase in the number of strings in the suspension insulator will permit the use of a limited increase in line voltage.

3. Static shields in requisite forms will lower maximum unit voltage duties so as to permit the satisfactory insulation of lines for the use of voltages far above 150 kilovolts.

THE M. I. T. COOPERATIVE PLAN A SUCCESS

For the past year an interesting experiment in cooperative engineering education has been conducted by the Massachusetts Institute of Technology and the General Electric Company. While the cooperative scheme in itself is not new, several departures from the usual plan have produced decided results.

The class was limited to thirty students, who were chosen entirely upon the records which they had made in the equivalent of the first two years' work of the Electrical Engineering course at Technology. Included in this group were graduates from Yale, Harvard, Dartmouth, Princeton, the Naval Academy, besides men who had completed their first and second years solely at Technology. The year (12 months) is divided into four three-month periods, the students spending alternately thirteen weeks at the Lynn works of the General Electric Company and eleven weeks at the Institute, followed by a two weeks' vacation. The group at Lynn is housed together in a fine old residence which has been converted into a modern club house. No break is made in the major studies when the students are at Lynn,—courses being conducted at the Works in principles of electrical engineering and in general studies. The progress of the students through the plant is regulated, not by the production needs of the various deprtments, but by the advantage which the experience in each department is to the students.

The result of this year's work has been gratifying to the originators of the plan. Because the students were a selected group, were all taking the same course, and were thrown together intimately at work and at the club house, an intense spirit of loyalty to one another, to the Institute and to the General Electric Company soon became manifest and every man strove to make a reputation for the course. With the students attacking the work in this frame of mind, it is not surprising that their enthusiasm was soon shared by the officials and superintendents of the cooperating company, who are unanimous in stating that the work done in the shops has been preeminently satisfactory. As evidence of its approval of the work, the company has increased the number of men who can be enrolled in this year's class to sixty and has already secured a new club house in order to furnish rooming accommodations for them. The new class which has already nearly completed its quota of members will enter upon the work, July 6.

During the month, the final list of changes proposed for incorporation in the National Electrical Safety Code was sent out by the Bureau of Standards. As soon as comments from interested parties have been received, the new edition of this code will be sent to the printer and it will be available for distribution late in the summer. A similar stage has been reached in the case of the first edition of the National Safety Code for the Protection of the Head and Eyes of Industrial Workers. This code is being prepared in cooperation with an advisory committee of experts in this subject and final changes have been sent to the Committee for consideration. This code also is to be printed in the near future.

Application of Mild and Alloy Steels to High-Tension Suspension Lines

BY L. R. O'NEILL

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A discussion of the application of stamped and pressed steel units of mild, structural and alloy steel to the suspension problem in high-tension transmission.

Factors to be considered in the design of hardware for line construction.

THE tremendously rapid development of long distance transmission of electrical energy at high potential involves most interesting problems in line construction and in insulation. As the structural engineer has been called on to design steel towers to support 500 foot spans and the ceramic engineer to develop porcelain capable of insulation against potentials of 150,000 volts, so the mechanical engineer finds opportunity for the application of his knowledge and training in the development of metallic units involved in the suspension of the line itself. His problem is the development of a suitable means of connection between the tower, the porcelain insulator and the line. The result of his work must insure a mechanical strength as high as the porcelain, the weakest element in the chain, it must be capable of application to the porcelain with due consideration for the wide range of temperature coefficients, and it must finally be capable of adequate protection against atmospheric and gaseous corrosion. Although the hardware element of the line is at first thought a problem of minor importance, it should be given just as careful study as any other element of the line in order to offer the highest possible degree of insurance against interrupted service.

Briefly stated, the hardware problem involves the production of units having a yield point as high as the highest strength of porcelain insulators, the lightest possible weight to insure that strength, a means of application which will offset, as far as may be, the variation in volumetric expansion due to extremes of temperature and finally a construction which will permit the most complete protective measures possible. Although the initial cost of installation generally is a factor of relatively minor importance and subservient to the consideration of longevity and efficiency, that cost is still worth serious consideration as the dollar value changes and all costs advance to hitherto unheard of altitudes.

A study of existing high-tension lines and their history shows that practically nothing has been seriously considered in the design of line hardware other than malleable and grey iron castings and drop forgings of mild steel. The reasons are quite obvious. High tension designing is relatively a new art. The large number of engineers engaged in its pursuit have an almost equally wide range of ideas of design; the rapid development of the art itself has made necessary frequent changes of design. Both castings and forgings are comparatively easy to change, the change involving, as a rule, no great cost. Until 1916 malleable iron castings were relatively inexpensive and the original pattern cost is so small as to add but slightly to the cost of the finished unit. As in many other lines of industry, we find a decided lack of familiarity with the possibilities of working sheet steel into such shapes as come within the field. As an example of this particular point it is only within the last year or so that the manufacture of heavy truck brake drums has been accomplished except by casting them of steel. They are now made by drawing a drum of suitable size and weight from a flat sheet. Such a drum is stronger, more nearly perfect as to shape and requires less machining. Examples such as this might be taken from a dozen different fields. We have all been perhaps somewhat slow to consider or to adopt pressed steel designs, electrical engineers because they did not know just what could be done in that field, the pressed steel engineer himself because it is only within the past few years that he has been able to do it. Beside other limitations it has been difficult for him to obtain from the steel mills a raw material of sufficient homogeneity and uniformity of chemical composition. to permit practical manufacturing operations. Similarly it is only within the last few years that the makers of cutting steel have developed a product suitable for long continued operations of such intricacy and severity as is required.

These conditions are now overcome. We can run 100,000 units through production involving severe drawing and forming operations and have a total loss of less than 1 per cent due either to material or workmanship. Our cutting steels are reliable and relatively inexpensive, the development of the art of high-tension transmission is itself sufficiently settled to permit quantity production, and finally the cost of forgings and castings, because both involve the use of skilled labor, has risen out of all proportion. The field is now open to stampings and it seems proper that we should consider what can be done and how it can be applied to the problem in hand.

In reply to that question, the presse dsteel manufacturers say that practically anything can be made in pressed steel, provided the quantity warrants the ef-

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fort. The various insulator manufacturers have each their own ideas as to the proper way to apply a porcelain insulator to the line. We have heard the claims made by those who believe in the cap and pin type and in warm opposition thereto the claims of those manufacturers who believe only in the spider type. One engineer asserts that a line clamp should not clamp the line at all but merely support it. The next engineer asserts quite as positively that a line clamp should be capable of resisting at least a 600-pound pull in tension. We are told that a strain clamp should be used by separating the steel core from the body of the cable and we are also told that this should never be done. It is not at all the province of the pressed steel engineer to discuss these points; they belong distinctly to the electrical engineer. It is our function to meet each one on his own ground and out of our own knowledge and experience in working steel offer him a construction and design which will meet his particular requirements. It is as easy or as difficult for us to make a suitable cap as it is to make a suitable spider. We can make a strain yoke out of a single piece of merchant bar 1/4 in. by 2 1/2 in. or out of a flat sheet 1/8 in. thick and perhaps 16 in. square. If our client today requires a line clamp which will solidly clamp the cable with a clip or a bridge plate we can do it. If tomorrow he prefers a clamp which will exert less pressure, that is equally easy or equally difficult. If you will consider the variety of odd shapes and strange sizes now being made in heavy presses you will be amazed. Axle housings, engine oil pans, railway ties, car seat pedestals, wire wheel hubs, clutch housings, interior wiring devices such as junction boxes, switch housings and bosses, all these are live testimony to the possibilities of the trade. Whether the design required metal in thousandths of an inch or quarter of an inch one has but to design suitable tools and feed the steel into a press. If cross-sections of varying thickness are required, they can be obtained by folding the metal on itself or by varying the thickness in the course of the drawing operation. If the desired shape cannot readily be formed from a single sheet, welding, either electric or touch is available and a perfectly reliable unit results. The uniformity of the product greatly reduces and usually eliminates machining and grinding operations; the unit is ready for use when it comes from the press. Of course such designs require careful study and a considerable knowledge not only of the art of working sheet steel but involve at least some degree of familiarity with problems of the electrical engineer.

Having in mind that we are presenting something relatively new, we ask that you consider what advantages pressed steel offers over malleable castings and forgings. Pressed steel units are uniform. You may pick up half a dozen units from a pile and caliper them, not with a scale but with a micrometer, and you will find variations which are to be measured in only a few thousandths of an inch. Holds line up perfectly. Caps are of absolutely uniform inside and outside diameters within a few thousandths of an inch. There is a corresponding uniformity of thickness and weight as well as finish. Uniformity such as this makes for easy handling and less expensive assembly with a complete absence of rectifying operations and fittings. Neither malleable, castings nor forgings are capable of such uniformity. The very nature of a casting involves considerable variation as to size and weight and one has only to go into an insulating plant to see castings being straightened with a hammer and filed or ground before they can be used. There is always a great variation in forgings and the flash or fins left by the dies is a variable factor, frequently involving more or less work before the unit can be used.

The physical strength of the unit is assured. The malleable iron casting is made by pouring molten iron into a mould, cooling and annealing in a furnace. You insulator manufacturers know how difficult it is to keep a furnace temperature absolutely uniform and to be sure that every cubic foot of the interior of the furnace is at the same temperature as every other cubic foot. If these conditions are not at least approximated in annealing castings, there is a wide range of temper and consequently of strength. Forgings are subject to similar possibilities of defect. If steel is handled under a drop hammer at too low a temperature, crystallization begins and the unit lacks the strength it should have. All pressed steel units are free from such defects and require only the most casual inspection and test. The steel itself is made in either an open hearth furnace, a Bessemer converter, a crucible or possibly an electric furnace. It is poured into ingots and from each heat a sample is taken which is submitted to physical and chemical analyses to insure that the ingot itself is of the desired quality. The ingot is rolled into the desired shape and inherent defects in the steel show almost automatically in the process of rolling. When the steel reaches our hands its percentage of imperfection is very low indeed. In the course of making a particular unit the steel sheet is blanked, drawn, formed and stamped, each of these operations requiring the application of such loads as invariably bring out any imperfections which still remain. In the making of a spider for example, the blank is cut out of the steel with its six or eight legs in a plane. Some 280 tons are required to effect this blanking and under such pressure any defects in the steel become immediately visible. Following the blanking, the spider is formed up into its cup shape by pushing it through a cylindrical die, involving a pressure of perhaps 175 tons. The steel is here given a relatively sharp right angle bend and if there be a pipe or seam in the sheet it is shown at once. In like manner the various severe operations which are performed cold on sheet steel to effect the desired results are such as to bring out any imperfections which the

steel may have. If malleable iron castings are to be used they must be designed with a very high safety factor and even then the production manager will have his troubles. The percentage of rejections on malleable iron castings are very much higher than in any pressed steel construction and in order to find out these rejections more or less elaborate testing facilities must be used on every piece. We do not need such tests with steel units. Forgings are less open to the criticism here applied and may properly be considered quite as satisfactory as pressed steel units in this connection.

The problem of protection against the corrosive action of the atmosphere and such influences as exhaust gases from locomotives and other sources has been given increasingly greater consideration during the past two or three years. Pressed steel units lend themselves better than any others to adequate protection by galvanizing, lead coating or enameling. They are clean and clear cut. Malleable castings show a certain inevitable percentage of units in which minute particles of slag and other impurities are imprisoned in the surface. Zinc applied by either the galvanizing or sherrardizing process to the castings cannot completely cover these tiny particles, an oasis is formed and in due time the salt air works its way along this little pinnacle of slag and underneath the zinc coating and our old enemy rust commences its work. Steel has no such surface imperfections and its protective coating is complete and impenetrable.

There is an unlimited supply of raw material of wide range. Units such as we are interested in can be made of anything from tank steel having an ultimate tensile strength of from forty to fifty thousand pounds to the square inch through the various grades of mild and structural steel having an ultimate tensile strength of approximately 75,000 pounds to the square inch up to alloy steels which include Chromium, Molybdenum and nickel which, with suitable heat treatment, will achieve an ultimate tensile strength of 180,000 pounds to the square inch. Malleable iron castings are limited to a narrow range of strength which may not extend beyond 44 or 45,000 pounds to the square inch. The relation of the yielding point to the ultimate tensile strength in steel may be quite definitely controlled within a considerable range and in the case of alloy steels, by proper heat treatment, may be brought up to 80 per cent of the ultimate strength insuring the highest possible usable strength with the least possible weight. Such a range of material from which to choose for our production certainly demands serious consideration.

The readiness with which the raw material itself can be secured is also a considerable factor. Go, if you will, to a malleable foundry and ask for 500 tons of malleable castings and at the same time ask a steel mill for 500 tons of sheet and learn for yourself at first hand which is the easier to obtain.

Both malleable iron castings and drop forgings involve of necessity the use of skilled labor. The enormous increase in the use of malleable castings and drop forgings in the automobile industry has resulted in demands on the foundries and forges which they cannot possibly fill, partly because of lack of equipment and partly because of the shortage of skilled labor. One cannot make a moulder or a hammerman overnight. If pressed steel constructions are used the employment of a relatively small number of very highly skilled mechanics is necessary only for the making of tools. The actual production of the unit itself is in the hands of unskilled labor which not only works at a relatively low wage but can be trained in two or three days to a high degree of efficiency. As in the production of the steel itself the machine does the work.

Quick deliveries are possible in steel. The ready availability of raw material and the relatively short time required to make tools insures an early start on the work. Most of the units which are likely to be used in this field can be turned out at the rate of at least from three to four hundred per hour and can be finished within the time required to put them through the various operations. Malleable iron castings must be annealed and the annealing process takes from three to seven weeks. The first piece must perforce wait on the necessary pattern equipment. Drop forgings cannot be handled so rapidly. The tools take practically as long to make as tools for sheet steel construction and it is never quite so easy to get exactly the right sizes of steel required to make a forging as it is to cut up a sheet of steel to the dimensions suitable for blanking. When a contract is finally let for the construction of a line, someone invariably wants hardware about two or three days later. It is certainly worth while to know that pressed steel units can be turned out in quantities in generally less time than any other construction.

Finally, we have to consider the question of cost. One is no longer shocked at being asked to pay from 12 to 18 cents per pound for malleable iron castings and prices as high as 24 cents per pound are not exactly new. The initial cost is not the only cost because extra fitting and inspections are required. Drop forgings at 12 cents per pound and higher are not uncommon. In contrast with these prices the raw material used for pressed steel units costs from 7 to 12 cents per pound for the steel best suited to this work, although alloy steels which are eminently desirable for certain conditions of extreme load may cost as much as 80 cents per pound. Very little calculation is required to show that the net cost is somewhat lower when operations which rarely number more than ten are performed at a rate of from three to five hundred per hour. The cost of tools which must naturally be amortized over the entire production is a factor of considerable importance. Generally speaking, the larger the unit by weight the lower the price because the labor

element of the cost remains practically the same, and it is probably safe to say that when pressed steel designs can be offered in lieu of castings or forgings the price will be somewhat lower and as a result of our experience there seems little reason to doubt that their efficiency is considerably higher.

In conclusion the engineers who represent the various pressed steel manufacturers are ready and willing to handle such problems as you may offer them, to apply the fruit of their experience in other lines and to work in close cooperation with you in the development of the high-tension lines.

Bridge Methods for Alternating-Current Measurements

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THE extension of the field of application of electric energy to human service requires more and more of measurements of electrical quantities, of varying grades of precision. Very prominent in the history of electrical measurements is the so-called "bridge" method, the fundamental principle of which is the equalizing of the potentials of two chosen points in a network of electric circuits. The original application of this principle was made by S. H. Christie in 1833 to the measurement of resistance to direct current in the arrangement long familiarly known as the Wheatstone Bridge. Numerous forms of Wheatstone Bridge for direct-current measurement have been developed. The conditions for its use have been investigated thoroughly and are well-known.

Of later development and less known and understood are the applications of the bridge principle to measuring impedances of alternating-current circuits. However, the knowledge of the Wheatstone Bridge as used with direct current can immediately be made use of for alternating-current testing by applying the principle stated by Kennelly in the following words.[1]

> It is however, a seemingly universal and a wonderful law, that all the numerical formulas and rules of quantitative behavior for continuous-current circuits, or conductors, are exactly the same for single-frequency alternating-current circuits or conductors, in respect to potentials and currents as also (with minor reservations) to power and energy if these formulas and rules are interpreted as relating to complex numbers.

The purpose of this paper is to present a resumé of simple methods of utilizing "bridge" networks in alternating-current measurements of impedances and their components of effective resistance, self and mutual inductance and capacitance, and in frequency measurement.

A great variety of arrangements have been described by numerous writers. It is not attempted to include all of these, but to present such a group as will give latitude of choice to suit the apparatus that is available, or permit the use of several methods to check against each other. By the methods shown approximate measurements over wide ranges of values can be made with very simple apparatus. It is hoped that others will add from their experience to the value of the collection.

Before taking up the various practical forms of bridge network, it will be helpful to consider the conditions for balance and other characteristics of a "Wheatstone bridge" wherein the four resistances are replaced by impedances. Thus generalizing the Wheatstone bridge network and utilizing the ordinary formulas in accordance with the principle quoted from Kennelly's statement given above, the relations shown

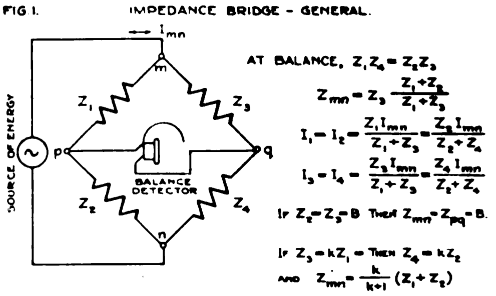

FIG. 1

in Fig. 1 are determined. In place of resistance is written the impedance.

$$Z = \sqrt{R^2 + X^2} \,/\theta = R + jX$$

Where R = effective resistance

X = effective reactance (+ if inductive, − capacitive)

$$\theta = \tan^{-1} \frac{X}{R}$$

The standard rules for combining complex numbers must of course be observed in using the formulas. Besides the formula connecting the several impedances at balance, the impedance of the whole bridge between the corners m and n is given, also the division of current among the branches. These are useful when it is necessary to determine the current input to the circuit whose impedance is being measured. It is of interest that when two opposite impedances of the network, as Z_2 and Z_2 or Z_1 and Z_4, are equal, the impedances Z_{mn} and Z_{pq} are alike equal to that same value.

Interchanging the energy source and balance detector connections, (energizing at p, q, and equating the

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1. Kennelly—Hyperbolic Functions Applied to Electrical Engineering.

potentials of m and n for balance) the same impedance relation prevails for balance, but the impedance, Z_{pq}, is in general different from Z_{mn}. Thus,

$$\frac{Z_{pq}}{Z_{mn}} = \frac{(Z_1 + Z_3)\,(Z_2 + Z_4)}{(Z_1 + Z_2)\,(Z_3 + Z_4)}$$

$$= \frac{Z_2\,(Z_1 + Z_3)^2}{Z_3\,(Z_1 + Z_2)^2}$$

When $$Z_3 = kZ_1$$

$$\frac{Z_{pq}}{Z_{mn}} = \frac{Z_1 Z_2}{(Z_1 + Z_2)^2}\;\frac{(I + k)^2}{k}$$

The arrangement to be used in practise to secure greatest sensitivity, for a given departure from the balanced condition, depends on the impedances of the branches, including the balance detector and energy source, and on the kind of circuit being measured. For example, where a telephone receiver is used, the disturbing extraneous noises may be less with one connection than the other. If the balance detector has higher impedance than the energy source, it should

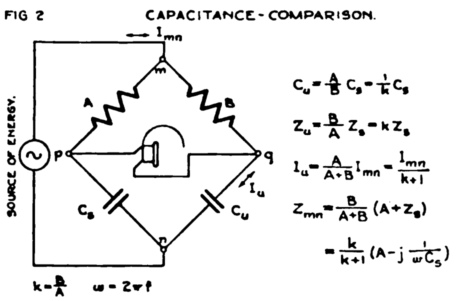


FIG. 2

be connected between the two opposite points of the network having the higher impedance.

Specific applications of these general formulas, and examples, will be given below. It is to be observed that the bridge methods here described provide for comparisons among resistances, inductances, capacitances, etc. and not for absolute measurements of any of them in terms of the fundamental units.

Fig. 2 shows the arrangement (due to De Sauty) for comparison of two capacitances. For the standard capacitance a variable condenser may be used, or with a fixed condenser the ratio of A to B can be adjusted, as by having A and B in the form of a slide wire. Variable resistance boxes, such as are found in Wheatstone bridges are also convenient for A and B. It is to be noted that the ratio $\frac{A}{B}$, the multiplier for obtaining C_u, is the reciprocal of the factor $\frac{B}{A}$ for Z_u and R_u since the impedance of a pure condenser is inversely proportional to its capacitance. C_s should be as nearly as convenient of the same magnitude as C_u. The method allows of precise adjustment for balance only when the two capacitances have very closely the same power factor, as for example the case of comparing good mica condensers.

Where the power factors of the standard and unknown condensers are different, and in general for measurement of capacitive impedances, including both resistance and capacitive reactance components, the form shown in Fig. 3 (due to Wien) can be used. A variable resistance r is arranged so it can be made part of either R_s, the effective resistance of the "standard" arm, or R_u, the effective resistance of the "un-

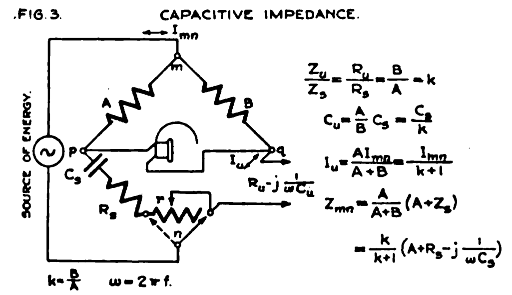


FIG. 3

known" arm. If the standard condenser C_s has a very small energy loss or effective resistance component, as in the case of a good mica condenser or an air condenser, R_s will be practically identical with its component r, external to the condenser. Mica condensers have phase angles of from one or two minutes up to six or seven minutes or more, depending on their quality. At 1000 cycles per second and with a 0.1 microfarad condenser having a phase angle of five minutes the reactance is $\frac{10^6}{2\,\pi\,1000 \times 0.1}$ or 1592

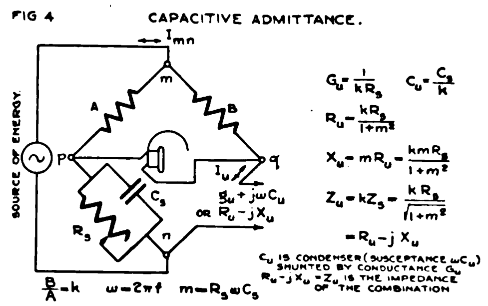


FIG. 4

ohms. The resistance is then 1592 sin 5 minutes or 2.3 ohms. For ordinary work, therefore, the effective resistance of a mica condenser can be neglected. With paper condensers much greater effective resistances are encountered.

The arrangement of Fig. 4, where the standard resistance and condenser are in parallel, may be designated as an admittance bridge, since it is adapted to determine more directly conductance $\left(g_u = \frac{A}{B\,R_s}\right)$, sus-

ceptance $\left(b_u = \omega C_u = \dfrac{A}{B} \omega C_s \right)$ and admittance $\left(Y_u = \dfrac{A}{B} Y_s \right)$ than the form previously described. Impedances may also be calculated from the values of R_s, C_s, A, B, and frequency f.

Whether the method of Fig. 3 or that of Fig. 4 shall be used may depend on the range of the apparatus available. As an example, let $B = 2A$, and consider the necessary values of R_s and C_s for the case where Z_u is a resistance of 1378 ohms (R_u) in series with a condenser of 0.362 microfarads (C_u). Then with the arrangement of Fig. 3 (R_s and C_s in series) the setting of R_s is 689 ohms and C_s is 0.724 microfarad for all frequencies for which the given values of R_u and C_u hold true. With the arrangement of Fig. 4 (R_s and C_s in parallel) $R_s = 800$ ohms and $C_s = 0.100$ microfarad at $\omega = 5000$ ($f = 796$ cycles per second). For other frequencies the Fig. 4 bridge values would differ.

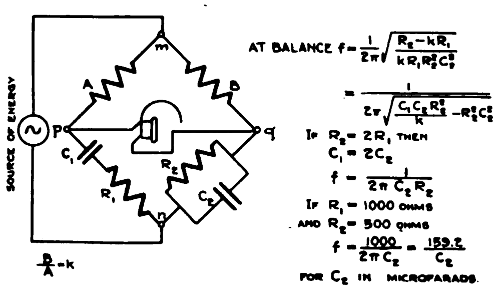


FIG. 5

The above example illustrates the fact that the shunting of a condenser by a resistance affords a means of increasing its effective capacitance. This is shown more fully in the curves of Fig. 18 for a capacitance $C_2 = 0.1$ microfarad shunted by a resistance R_2 varied over a wide range, the frequency chosen being $\omega = 2\pi f = 5000$. The effective capacitance of the combination is C_1, and the resistance, R_1.

A method is thus afforded for using a fixed condenser as C_s for measurements with the Fig. 4 bridge. On account of the variations of the effective resistance, (see R_1 of Fig. 18), additional series resistance (like r in Fig. 3 and 6) is necessary to obtain balance.

The effective inductance of a fixed inductance coil can be varied in like fashion to the condenser just described. Referring to the case of Fig. 18, for the chosen frequency, a self-inductance of 0.4 henry (of low resistance) shunted by resistance R_2, exhibits the same effective reactance (X_1) and resistance (R_1) as the condenser C_2 of 0.1 microfarad. The effective inductance L_1 is always *less than* L_2.

A bridge method of determining frequency, using resistance and capacitance only, connected in series on one side and in parallel on the other, is shown in Fig. 5. The formula for the general case is rather complicated, but by choosing the shunt resistance R_2 equal to twice the series resistance R_1, the condition for balance is $C_1 = 2C_2$ and the frequency is

$$f = \frac{1}{2\pi C_2 R_2}.$$

By setting $R = 1000$ ohms

$$f = \frac{1000}{2\pi C_2},$$

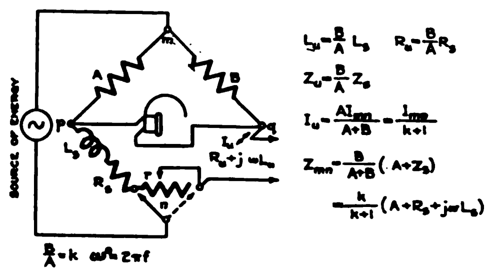


FIG. 6

C being expressed in microfarads. A corresponding method might be used employing inductances of low effective resistance.

A bridge for the direct comparison of inductances and measurement of inductive impedances (due to Maxwell) is shown in Fig. 6. As in the case of the bridges already described, a slide wire may be used to form A and B arms, with a fixed inductance L_s. A shunted inductance can also be used for values below the range of L_s. To measure inductances higher than

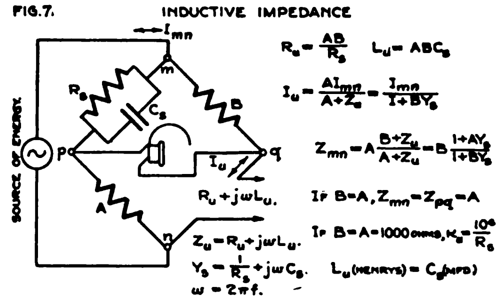


FIG. 7

$k L_s$, a condenser may be connected in series with Z_u. A condenser of capacitance C' can be considered as a negative inductance of size $L' = \dfrac{1}{\omega^2} C'$. The inductance L_u will than be $k L_s + L'$.

Methods will next be described for comparing self-inductance with capacitance, or stated more generally, of determining inductive impedances by comparison with capacitive impedances, or vice versa.

Fig. 7 shows an arrangement (due to Maxwell) much used for determining inductive impedance in terms of a resistance and condenser. It can, of course

be used also for the converse process. A series resistance and condenser can be used in place of R_s and C_s, but the formulas are less simple. This form is not shown. Especially simple calculations are afforded for the Fig. 7 bridge by making $A\ B$ (each in ohms) equal one million. Ordinarily R_s and C_s are the variable elements, but balance is obtainable by varying others such as A, B or L_u. A vector diagram of currents and potential differences of this bridge is shown in Fig. 17, which gives data of a numerical example.

In Fig. 8 is presented a modification of the bridge just described, known as the Anderson bridge. A resistance r is connected between condenser C_s and corner p, and the detector is connected to the junction of r and C_s. By varying r, a fixed condenser C_s can be used for inductive impedance measurements over a wide range. Where r is large it has been found advantageous to interchange the energy source and the detector.

Fig. 9 presents a bridge set-up suitable for making measurements in quick succession of capacitive and inductive impedances. For measuring capacitive

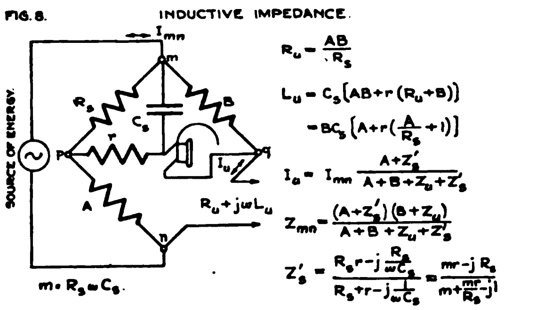


Fig. 8

impedances, it is the same arrangement as that presented in Fig. 4. By switching the condenser C_s so that it is connected from n to q, instead of to p, balance is obtained for an inductive impedance Z_u. The same formulas apply in each case, changing sign of the reactance X_u, when ratio arms A and B are equal. This bridge can also be used to determine frequency.

The bridge shown in Fig. 9 may be described as a resonance bridge, when X_u is inductive, since the arm $n\ q$ is made nonreactive at balance. A well-known and widely useful resonance bridge is shown in Fig. 10, which can be used to measure either inductive impedance $(R_u + j\ \omega\ L_u)$ or capacitive impedance

$$\left(R_u - j\,\frac{1}{\omega\, C_s}\right)$$

by using variable series capacitance C_s or inductance L_u to resonate the branch $n\ q$. It is also a convenient means of determining the frequency, using fixed condenser and variable self-inductor or vice versa. With a variable standard inductance this arrangment can be used like that of Fig. 9 for measuring inductive and capacitive impedances alternatively by simply placing the variable inductor in the $n\ q$ branch for measuring capacitive impedance, or in the $n\ p$ branch for inductive impedance, as was shown in Fig. 6. The methods described on page 6 for securing variation of effective reactance of fixed condensers or inductances can be applied to this bridge.

Next to be considered is the measurement of mutual inductance. A method which is also applicable to mutual capacitance and resistance, or stated generally, to mutual impedance determinations, makes use of bridges such as those already described. Consider two circuits, of impedances Z_2 and Z_2 respectively,

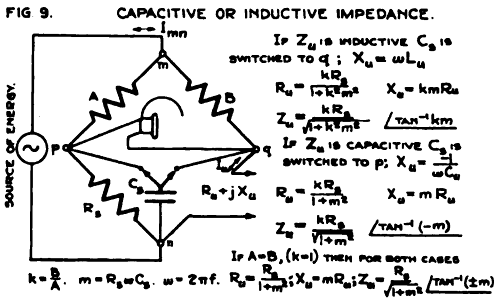


Fig. 9

and mutual impedance Z_m[1]. If connected in series the resultant impedance is $Z_a = Z_1 + Z_2 - 2\,Z_m$. By reversing the connections of one of the two, the sign of the Z_m term is reversed and the impedance is

$$Z_b = Z_1 + Z_2 + 2\,Z_m$$

Z_1 and Z_2 can be eliminated from these two equations leaving

$$Z_m = \frac{Z_b - Z_a}{4}$$

Where one terminal of Z_1 and Z_2 is common, for example the case of two earth-return wire circuits, the above

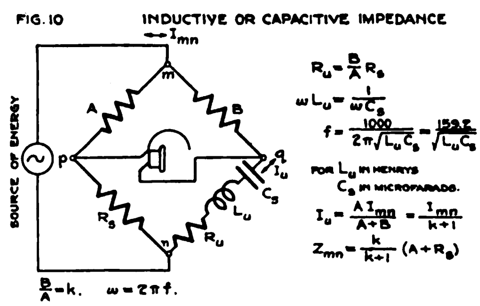


Fig. 10

procedure for obtaining Z_b is not possible. However by measuring Z_1, Z_2 and Z_a, Z_m can be evaluated, for

$$2\,Z_m = Z_1 + Z_2 - Z_a.$$

A check may be had by measuring the impedance Z_{12-0} from the two free terminals in parallel to the common terminal, but the formula for Z_m is complicated, being

$$Z_m = Z_{12-0} \pm \sqrt{Z_{12-0} + Z_1\,Z_2 - Z_{12-0}\,(Z_1 + Z_2)}$$

The use of this method and of the Fig. 10 bridge will

1. See Bibliography No. 5.

be illustrated by measurements on a retardation coil having two windings on an iron-wire core.

The frequency was first determined by balancing a 0.1004 microfarad condenser (C_s) with an inductance L_u = 0.379 henry, (using an inductometer), R_s being adjusted but its value not required. A and B were each 1000 ohms resistance. Their values likewise are not required for finding the frequency

$$f = \frac{159.2}{5.379 \times 0.1004} = 816 \text{ cycles per second.}$$

$$\omega = 5130. \quad \omega^2 = 26.3 \times 10^2$$

The resistance components, being small compared to the reactance components will for brevity be omitted from consideration, leaving only the reactances. The factor ω then cancels out, thus

$$Z_m = \frac{Z_b - Z_a}{4}$$

becomes $\omega M = \dfrac{\omega L_b - \omega L_a}{4}$

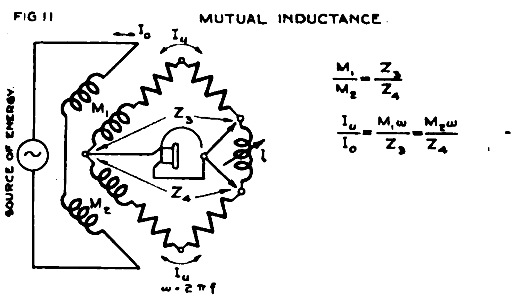


Fig. 11

or $M = \dfrac{L_b - L_a}{4}$

To find L_a, with the two windings in series aiding, C_s = 0.0141 microfarad whence

$$L_u\ (= L_a) = \frac{10^6}{\omega^2 \times 0.0141} = 2.70 \text{ henrys.}$$

Reversing connections, placing the two windings in series opposing; to find L_b, C_s = 0.0232 microfarad,

$$\text{whence } L_b\ (= L_u) = \frac{10^6}{\omega^2 \times 0.0232}$$

Thus L_u = 1.64 henrys.

M = 1/4 (2.70 − 1.64) = 0.265 henry.

The impedance of one winding, Z_1 the other being open-circuited, was as follows:

C_s = 0.0348 microfarad. R_s = 254 ohms = R_u

$$L_u = \frac{10^6}{\omega^2} C_s = 1.096 \text{ henrys } X_u = \omega L_u = 5610 \text{ ohms}$$

whence

Z_u ($= Z_1$) = 254 + j 5610 ohms.

The direct comparison of two mutual inductances is effected by the bridge of Fig. 11 (due to Maxwell). The impedances Z_3 and Z_4 include the inductive reactances and resistances of the secondaries of the mutual inductance coils M_1 and M_2, besides variable resistance. The small variable inductance 1 is made part of either Z_3 or Z_4 and is necessary to equate the phase angles of Z_3 and Z_4. With M_1 and M_2 known this bridge is available for ordinary impedance measurements, also.

The circuit of Fig. 12 is a very convenient method of determining frequency in terms of mutual inductance and capacitance, or for measuring either of the latter, if the other and the frequency are known. It depends

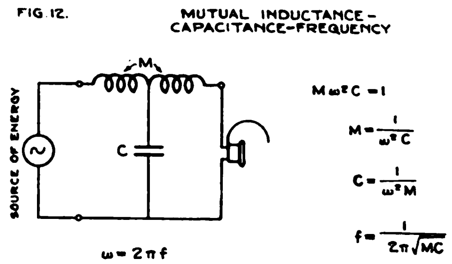


Fig. 12

for its effectiveness on the effective resistance components in the branch C and in the mutual impedance of the coil M being very small. If, due to eddy-current effects, the secondary induced e. m. f. of the coil M is not in quadrature with the primary current, or if there is energy loss in the condenser so that the potential drop across it is not in quadrature with the current, precise balance is not obtained. As an example, it was found impracticable to make a very close determination by this method of the mutual inductance of the iron-cored coil of which measurements were described above.

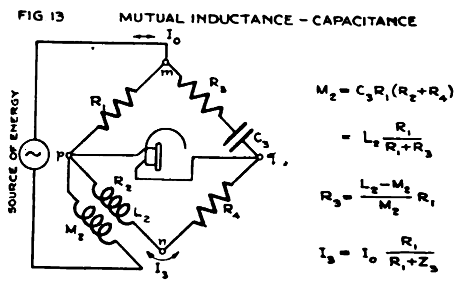


Fig. 13

Another bridge, (due to Carey Foster) for comparing mutual inductance with capacitance, is given in Fig. 13. The frequency is not involved in the equation. The method also permits the determination of the resistance of the arm containing the capacitance, so that the effective resistance of a condenser can be measured, and thus its power factor.

A bridge for comparing self and mutual inductances, (due to Heaviside) is shown in Fig. 14. A method of differences, (due to Campbell), which can also be applied in principle to other bridge networks, has been developed for the measurement of small self-inductances

using this arrangement. The bridge is first balanced, with $n - n'$ short-circuited. The inductance to be measured is then inserted between n and n' and the change in M_s to restore balance is observed. It is necessary that the self-inductance L_s of the secondary winding of the mutual inductance coil remain constant.

For the comparison of low impedances, for example in determining the conductivity of electrolytes, and cases where contact or leading in resistances are of importance, the Kelvin double bridge is used. The arrangement is shown in Fig. 15. Where, as in electrolytes, there is capacitive reactance effect, it may be necessary to shunt the standard resistance with a small variable condenser, to obtain exact balance.

An important use of bridge networks is the determination of unbalances, or the difference between two impedances or admittances; often of two sides of a circuit with regard to some common reference, usually "ground." The most obvious way is to measure each impedance separately. However, it is frequently the ratio of values that is desired and not the actual values. For this purpose, if the phase angles of the impedances

FIG. 14. INDUCTIVE IMPEDANCE-MUTUAL INDUCTANCE.

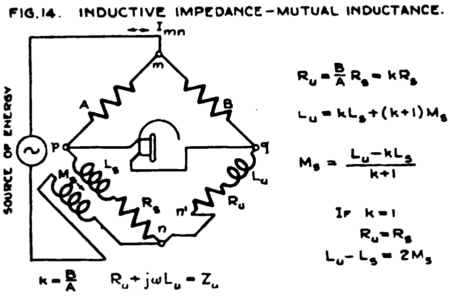


FIG. 14

being thus compared are nearly alike, the type of bridge shown in Fig. 2, 3, etc. having ratio arms A and B in adjacent branches, permits direct determination of the ratio of the impedances in the two other branches, by adjustment of the ratio $\dfrac{B}{A}$ to obtain balance. This method becomes unsatisfactory if the phase angles of the impedances being compared are unlike.

A bridge arranged to measure both conductance and capacitance components of the unbalance between two admittances Y_a and Y_b is shown in Fig. 16. As illustrated, a special condenser is so arranged that capacitance C is added to one side and subtracted from the other simultaneously as the condenser is shifted from its neutral position. The effect can also be secured by an ordinary condenser connected alternatively from p or q to n. A similar arrangement balances the conductances. At balance the readings of C and r show the difference between the two admittances Y_a and Y_b. To obtain the ratio or percentage of unbalance it is necessary to measure Y_a and Y_b.

The admittances of conductors sometimes depend on the condition of neighboring conductors. In the study of such cases the "direct admittances" are made use of.[2] The direct admittance between two conductors a and b is that admittance which obtains when all neighboring conductors are at the same potential as one of them. The dotted structure in Fig. 16 shows a method of adjusting the potential of conductors X to that of a and b, so that direct admittances or direct admittance unbalances can be measured.

In the above discussion of the various bridges where ratio arms have been shown they have been indicated

FIG. 15. LOW IMPEDANCE-KELVIN DOUBLE BRIDGE.

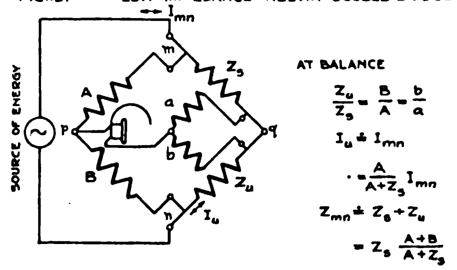
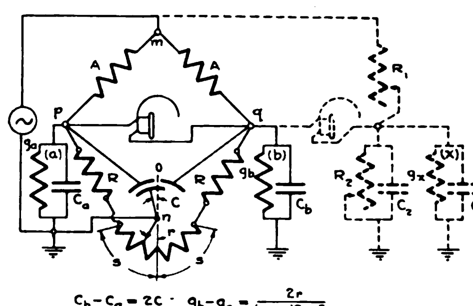


FIG. 15

as resistances, according to the common practise of using nearly non-reactive resistance coils or slide wires. In cases where such ratio arms A, B are in adjacent branches, any two impedances having equal phase angles, such as for example, two condensers or two highly reactive coils can be substituted for such resistances, without altering the formulas.

While the use of unequal ratio arms provides a flexible bridge and greatly increases its range, simplicity in calculation and the minimizing of errors due to inexact realization of assumed conditions (for example,

FIG. 16 ADMITTANCE UNBALANCE



APPARATUS SHOWN DOTTED CAN BE ADJUSTED TO EQUATE POTENTIAL OF OTHER CONDUCTORS, X, TO THE POTENTIAL OF a AND b, BEING MEASURED.

FIG. 16

residual inductance or capacitance in assumed pure resistance coils) dictate the use of equal ratio arms wherever practicable.

Several different types of sources of energy at frequencies over the range from direct current up to radio frequencies, or over parts of this range, are available. It is not attempted here to discuss these. Among such are the various forms of alternator with rotating armature or field, or of the inductor type, the singing telephone or "howler," the microphone hummer,

2. *See Bibliography No. 5.

the Vreeland sine wave oscillator, and, most recently developed, the vacuum-tube oscillator. For a full discussion the reader is directed to references of the bibliography.

The most commonly used balance detector is the telephone which has the advantages of cheapness, simplicity, and ample sensitivity for all ordinary testing. It is most convenient at frequencies of from about 300 to a few thousand cycles per second, though measurements can be made at somewhat lower frequencies with it directly. However, small higher harmonics in the wave from the energy source have so much greater a factor of audibility that a pure wave shape is needed.

A method was developed many years ago to adapt the telephone to the direct-current Wheatstone bridge. This can be employed for measurements at very low frequencies. It consists of varying at an audible frequency the impedance of the balance detector circuit, so that whenever any current of low frequency exists in this circuit it will be broken up into audible impulses. The early device was a toothed wheel interrupter. A

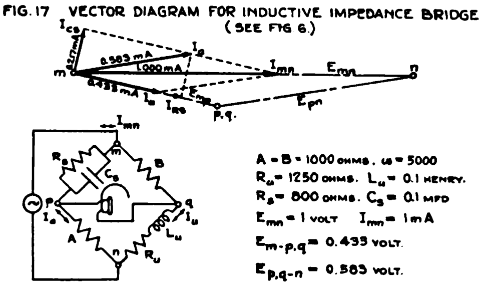


FIG. 17

modern method of achieving the same result is to connect a telephone transmitter in series with the balance detector telephone[3]. A telephone receiver, excited at an audible frequency, say 800 cycles is then used to operate the transmitter, thus varying the impedance of the detector branch.

For frequencies above a few thousand cycles, the heterodyne principle common in radio practise can be employed, the telephone receiver in the balance detector position being energized also by an auxiliary source of such frequency that the beats between the measuring frequency and this auxiliary frequency are audible.

Some forms of bridge, such as Figs. 2, 3, 7, etc. do not contain the frequency in the equation of balance. In practise this does not mean, however, that the bridge is simultaneously exactly balanced for all frequencies, because the resistances, inductances and capacitances usually change more or less with frequency. However, the tendency is toward balance, so that harmonics in the energy supply are not troublesome unless the wave shape is very poor. For other forms of bridge, such as Fig. 10, or any bridge that measures frequency, where balance is obtained by resonance, the bridge is definitely unbalanced at all frequencies other than the one for which the bridge is set. With such bridges purity of wave form of the energy source is important as observation of the silence point in a telephone receiver for one particular frequency becomes difficult or impossible as the noise from other harmonics is increased.

To purify the wave-form supplied to the bridge a filter or wave screen is often of advantage. The simplest form consists of an inductance coil and condenser in series with the energy source. It is also possible to resonate the detector circuit for the frequency under observation.

For precise work and especially at low frequencies the vibration galvanometer has been very successfully used. It is a much more complicated and delicate apparatus and is sensitively tuned to the frequency of the energy supply.[4]

As the frequency employed is increased the problem of guarding against current in the detector circuit, due

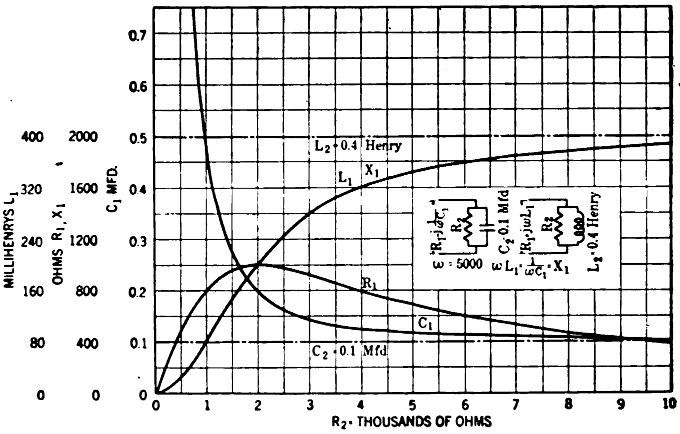


FIG. 18—EFFECTIVE RESISTANCE, REACTANCE, AND CAPACITANCE OR INDUCTANCE

Obtained by shunting condenser of 0.1 microfarad or inductance of 0.4 henry by a variable resistance, R_2.

to unbalances among the bridge arms and to ground, becomes more acute. To quote from Campbell:[5]

> The difficulty encountered lies mainly in the direct capacity between the different parts of the system. Since the ether permits the flow of alternating currents in all directions, the attempt to employ an ordinary balance for alternating measurements is much the same as the attempt to measure resistance with a Wheatstone bridge immersed in a conducting fluid, such as acidulated water.

For measurements at 1000 cycles and less this problem is only important in the more precise measurements. A simple device which is of aid in this connection is to connect the energy source to the bridge through a transformer having its neutral point grounded. Similarly, the balance detector may be connected to the bridge through a transformer. More elaborate arrangements are described in the literature.

A number of references to books and periodicals are

3. See Bibliography No. 11.

4. See Bibliography No. 1, 2 and Bureau of Standards Publication.

5. See Bibliography No. 10.

given below for the guidance of those seeking further information.

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4. Smith—Electric and Magnetic Measurements—(1917).

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The scientific papers of the Bureau of Standards contain many discussions of bridge measurements. Of especial interest are the following:

6. Brooks and Weaver—A variable self and Mutual inductor. Sci. Paper No. 290.

7. Curtis—Mica Condensers as Standards of Capacity. Bulletin, Volume 6, page 431.

8. Grover—Simultaneous measurements of Capacity and Power Factor of Condensers. Bulletin, Volume 3, page 371.

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10. Campbell—The Shielded Balance—*Electrical World and Engineer*, April 2, 1904.

11. Kennelly, Laws and Pierce—Experimental Researches on Skin Effect in Conductors. Trans. A. I. E. E., Volume 34, (1915).

12. Drysdale—A Universal Inductance and Capacity Testing Bridge—Electrician (London) January 23rd, 30th, 1920.

CORRESPONDENCE

A-C. vs. D-C. Arc Welding

To the Editor:

Referring to Mr. Candy's comments on a-c. welding equipment in his article published in the Journal for June, 1920, it must be that he has drawn his conclusions from apparatus which he has constructed for his company. At least we know that no part of his comments refer to our a-c. welding machine although the article definitely classes all a-c. welding as poor. For instance, he makes the statement, "To make the equipment commercially successful in the hands of the average welder it is necessary to use an especially prepared electrode."

We have many installations in which bare wire electrodes are used, and some of them are not very careful as to what kind of wire they use. There is a firm using our apparatus which uses the core stiffening wire as it is removed from the castings, to weld up defects in the castings. Another firm regularly uses ½-in. diameter contractor's concrete-stiffening rods for welding up defects in castings. We have found firms using any kind of wire from hay wire to rusty nails, for electrodes, and while it is our claim that the best welding cannot be done except with good electrodes, we hereby make the statement that our machine will use any electrode that any other machine will use.

Mr. Candy also makes the statement that the a-c. arc is not so effective in fusing the metal as the d-c., assuming current only. In welding, the metal is evidently melted by energy, and current is only one factor, and while it is true that the power factor of the a-c. welding circuit lies between 0.88 and 0.92, yet due to the temperature of the arc being higher, and because the electrode is neither positive nor negative and the heat equally distributed at the same current the rate of electrode deposition has equally good results in welding and will be approximately 20 per cent faster with our type of welding transformer.

He next states, "the transformer is inherently a single-phase low power factor load (20 per cent to 30 per cent maximum)" With our machine 33 1/3 per cent is the minimum, and it ranges from this up to 63%. The reason we make single-phase machines is because they are much simpler and hence portable, and 4, 5, or 6 kw. is not worth while to distribute among the phases. If more than one machine is used they will be automatically distributed. Spot and butt welding run many times this demand, and it is not thought inadvisable even by Mr. Candy's company, to make these single-phase machines. The broad way of looking at it is, in the case of one machine, the unbalance is negligible, and in the case of many machines no unbalance exists, on any number of phases.

We have often been asked why it is that the power factor of our machine is higher than either of the largest electric concerns is willing to admit. It is well-known that besides the proper transformer characteristics there is a proper amount of resistance and reactance which cause the best combination for good arcs. By using the highest priced materials we have put this resistance in the machine, at the same time reducing its weight and making it portable and air-cooled.

In regard to the statement, "No thorough satisfactory means of limiting the open-circuit voltage to reasonably safe values (60 volts or less) has as yet been developed." We have had on the market for a long time, and equip practically all of our machines with an appliance so that the maximum voltage occurring at any time is 30 volts, and even the peak of the inductive a-c. kick is well below 60, *i. e.* around 45 or 50.

Mr. Candy also states that the operating cost of the a-c. machine is so much higher than the d-c., etc. We have made many tests against every type of d-c. machine and found that our figures of 1 to 2 kw-hr. per pound of metal deposited have never been equalled by any motor-generator type of welding apparatus. Furthermore, we guarantee the maintenance on our machine because we have never found it to exist to an extent that could be noted.

C. J. Holslag, Chief Engineer,
Electric Arc Cutting & Welding Co.

Power Factor Correction on Distribution Systems

BY D. M. JONES

Lighting Engineering Dept., General Electric Co., Schenectady, N. Y.

Power Factor Correction on Distribution Systems

POWER factor is a characteristic of electrical energy which is being transmitted by an impressed alternating voltage and resultant alternating current whereby it is possible for the current to rise and fall in magnitude before, with or after, the equivalent rise or fall in the alternating electromotive force. Tied up with this relative timing of voltage and current waves (which make up one pair of the cause and effect twins of the electrical family) is much of the hope and grief of the distribution game.

Development of Distribution

The development of the art of distribution of electrical energy has been practically dictated by the developments in electrical energy producing and consuming devices. The demand that distribution systems cover over larger areas has forced higher distribution voltages. The safety of the consumer and lower relative cost of manufacture in case of most small electrical power consuming devices has kept the mass of consumers' services at a relatively low voltage. This conflict of requirements could only be adjusted by a practical pressure charging apparatus.

The advent of the transformer as a device which very neatly did this work in a-c. circuits, easily gave this type of service a big lead in the distribution field. This lead was accentuated by the discovery of the principle underlying the induction motor and subsequent production of this motor for general a-c. commercial motor service.

The ruggedness and simplicity of the electrical and mechanical design of both the wound-rotor and squirrel-cage types of this motor early caused it to be considered by the consumer a most satisfactory appliance for converting electric energy to energy of rotating motion, and this attitude has resulted in practical limitation of d-c. motors in industrial service to either those conditions where a-c. service was not available or to special applications where large speed variation was desired with relatively high torque at low speeds. In this latter field the d-c. motor is still pretty well entrenched on account of its inherent ability, not only to meet the above conditions, but even to do so with relatively high efficiencies.

Two notable exceptions to the above general tendency towards the use of alternating current, however, exist: The d-c. distribution networks covering the dense business sections of some of our largest cities; and the use of direct current in electrical traction activities.

The d-c. network generally has a basic historical reason for existence. The natural place for first electrical lighting plants to appear was in the heart of the largest cities and as these first plants were all d-c., the distribution systems in these spots started as d-c. systems. When the a-c. generating station arrived there was so much d-c. equipment in operation in the section, that it was less of a convulsion to substitute converting devices for changing the a-c. power received from new central stations to d-c. power to fit the old equipment, than to change our whole system to a-c., that this solution was generally adopted. Another potent argument for the d-c. service in these congested sections was the fact that it could be backed up with a storage battery; (generally of capacity to carry full load for 15 minutes) which did away with the possibility of short failures of power with attendant danger to life and property in these dense sections. Now, however, (a) the improvement in reliability of a-c. distribution due to the improvement of general equipment and construction practises, and also to the development of automatic control features; (b) the relatively lower cost of a-c. distribution due to absence of synchronous converters and storage batteries and reduction in quantity of copper required due to the fact that with a-c. distribution the power is generally brought much nearer to consumer at the higher voltage; (c) the reduced upkeep and attention; due to absence of converters and batteries above mentioned; (d) and finally the habit a d-c. network has, when it once does go dead beyond the ministering aid of the storage battery, of going dead all over; have not left it in undisputed sway even here, but rather in the position where it must fight harder for its grasp on the situation with passing years; particularly, when it is a matter of determining the type of new installations.

In the traction field the incomparable excellence of the d-c. motor, as compared with the a-c. type, has always kept most of the trolley wires of the world carrying d-c. power. This has not been without aggresive competition, especially in the realm of heavy haulage where the a-c. motor bids fair to divide the honors for a time. At present, however, the ultimate distribution of the electrical energy for traction purposes is increasingly done in d-c. form.

Bad Power Factor a Dangerous Condition

It is thus evident from the foregoing that power factor, being a characteristic of a-c. distribution, is a phenomenon, whose field of influence already is widespread; and it is broadening at almost a cumulative rate. The fact that the electrical energy delivery team (current and voltage) in an a-c. system have the capacity of doing more or less work for their size, as

To be presented at the Pacific Coast Convention, A. I. E. E., Portland, Ore., July 21–23, 1920.

one might say, according to whether they pull together or not; suggests at once the advisability of seeing what can be done to get the most out of them. This advisability is accentuated by an appreciation of the fact that the capacity of the electrical end of generating equipments and distribution systems is based upon the size of "current" the "off-horse" of this team, and not upon the work the team accomplishes. And again, since the electrical losses throughout are dependent, not only upon the magnitude of the current value alone, but even increase with the square of the current value, it is evident that in a large measure this animal also eats according to the size of his frame and not according to his productive activities.

Its Relation to Capital Invested

The fact that the load of power systems varies cyclically with the hours of the day and that the maximum current demand for the day, in the past, has generally come with the evening lighting peak, which is an inherently good power factor load, has made many careless as to what the power factor of the lesser loads through out the day was, as the lighting peak had dictated the current-carrying capacity of the distribution system.

When this low power factor industrial load, which had generally been welcomed at a reduced rate as a filler of load curve valleys, began to demand the expenditure of money for distribution capacity due to its presence, beyond that which was demanded by the evening peak, it challenged attention to the seriousness of the evils of bad power factor from the economic standpoint. For example; the capital cost of central station system beyond the generating station bus per kilowatt-hour delivered per year will vary over range of approximately 2 cents for large dense installations to 12 cents for small extended distribution systems. Assuming 4 cents capital investment per kilowatt-hour delivered per year and 15 per cent interest and depreciation charge on basis of 90 per cent power factor at maximum current demand as a concrete case, the interest and depreciation on transmission and distribution systems per kilowatt-hour delivered will be 6/10 of a cent.

If the power factor of maximum current peak were now arbitrarily lowered to 60 per cent and load remained the same, and assuming general transmission and distribution investment were increased proportionally with current increase, the interest and depreciation per kilowatt-hour delivered for the year would be increased 50 per cent. The capital charge would now be 9/10 cent instead of 6/10 cent for each kilowatt-hour delivered; or an increase of 3/10 of a cent in delivered cost of every kilowatt-hour, due to increased capital charge occasioned by the drop in power factor from 90 per cent to 60 per cent lagging. Such a saving would buy the coal under average conditions for some plants.

Effect on Losses

The increased I^2R losses with the change for the worse of power factor are often considered negligible and are admittedly difficult to reduce to the concrete.

Let us consider however the copper losses in a three-conductor 250,000 cir. mil. distribution cable carrying 60-cycle 15,000-volt three-phase power, which is a fairly representative condition. Assuming an average daily load curve on the cable with load factor of 53½ per cent and current of 200 amperes at evening peak, as shown on Fig. 1 with power factor varying from 90 per cent at peak to 60 per cent throughout day as shown by power factor curve on above mentioned figure we have the following results:

Total kw-hr. per year delivered over cable 21,900,000.

Total I^2R losses for year per mile 144,000 kw-hr. Or about 66/100 of one per cent of power delivered disappear in I^2R losses per mile of cable. If now the power factor of above assumed load were brought up to a constant value of 90 per cent throughout 24 hr. the above results are changed as follows:

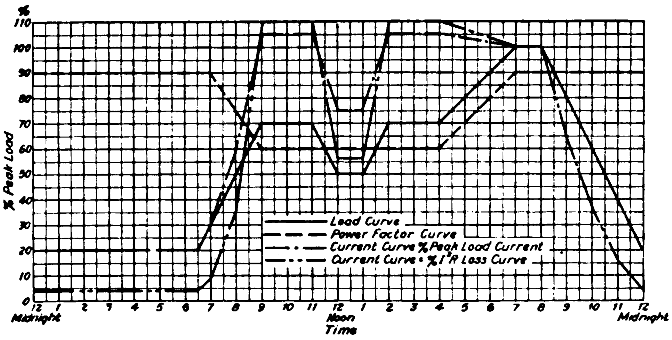

Fig. 1

The I^2R losses per mile per year are reduced, to 88,500 kw-hr. or about 4/10 of one per cent with a saving in losses of about ¼ of one per cent of power delivered per mile of cable carrying load under conditions as assumed.

In these days when demand for electric energy is in excess of the available supply, the elimination of losses means additional power sold. On this basis the raising of the power factor of the load up to a constant value of 90 per cent and resultant reduction in losses of ¼ of one per cent per mile of cable would make available for consumers 55,500 kw-hr. per year for every mile of distribution cable in service under equivalent conditions.

If this power were sold at 3 cents per kw-hr. a revenue of $1665.00 per year would be received per mile of cable for what under first condition went into heating the cable. Furthermore, the power would have become available during the day load period when wanted as shown by shaded area on Fig. 2.

Power Factor and Regulation

Besides these primary evils of excessive capitalization costs and unwarranted losses, the secondary effect

of bad regulation chargeable to bad power factor is in practical experience as serious as the primary evils.

The demand for excessive generator excitation under lagging power factor conditions so thoroughly appreciated by operators, though strictly beyond the scope of this discussion, cannot be passed unmentioned.

The excessive voltage variation produced in distribution wires and cables and especially on transformers by conditions of bad power factor are facts both within our field and worthy of consideration. This voltage variation is aggravated by conditions of power factor not only by the fact of the unnecessary magnitude of current for given power transmitted but in the case of the average condition, where the power factor is lagging, the delay of the current wave behind the voltage wave tends to make the voltage induced in the reactance of the lines and transformers directly subtractable from the generated voltage, while in case of unity power factor condition, this voltage is in quadrature and has small effect on magnitude of line voltage.

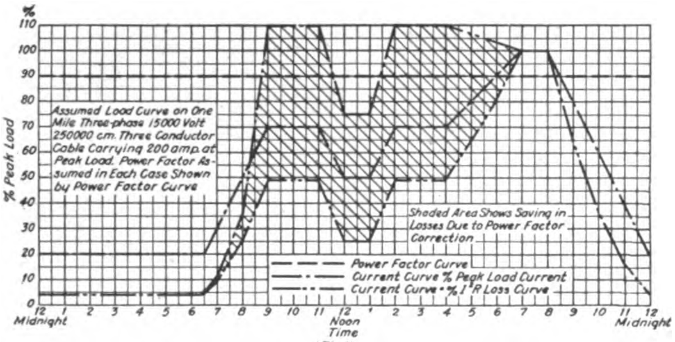

FIG. 2

As an instance of this consider the average 60-cycle 2300 to 220/110-volt type of distribution transformer. Such transformers are commonly produced with resistance of from 1 to 1¼ per cent and with reactance of 2¾ to 4½ per cent over range of capacity from 1 to 250 kv-a. or more. Full load on transformer of this type with say 1¾ per cent resistance and 3½ reactance means a drop in voltage at unity power factor of about 1.8 per cent of line voltage which at 0.7 power factor lagging becomes 3.7 per cent drop or a little over double what it was with the same current flowing in transformer as at unity power factor or nearly 3 times the drop that would have occurred in delivering same power at unity power factor.

In the case of the substation transformer working between voltages from 6600 to 15,000 volts or more down to voltages of 4600 volts or less, a representative example may be considered to have 1.3 per cent resistance and 6 per cent reactance. Here the full-load voltage drop with unity power factor would be about 1⅓ per cent of normal voltage, while with the same kv-a. load on transformer and power factor of 70 per cent lagging the drop would become about 5.2 per cent or nearly 4 times its previous value, and about 5½ times more than would have occurred on basis of equal power transferred. It is fairly evident therefore, that transformers become vicious voltage "ir-regulators" with power factor variation even at constant load.

Sources of Bad Power Factor

The review of these evils of bad power factor bring at once to mind the question of probable causes and available remedies for this condition.

The Induction Motor and Power Factor

Probably the most prevalent source of the trouble is found associated with the use of the induction motor.

The use of too large a motor, resulting, it is regrettable to say, from a misapplication of good intentions, is a practise which has been one of the chief offenders. Past experience in installing motive power of other than the electrical variety has taught the lesson of liberality in selection of capacity and this has naturally resulted in the same tendency in many cases in the selection of motor sizes.

The seriousness of the result will be appreciated when it is remembered that the lagging magnetizing kv-a. on general line of 60-cycle induction motors, runs from 30 to 60 per cent of the full load kv-a. and holds practically constant in a given motor over whole load range.

For example, consider an induction motor which at full load has a power factor of 85 per cent, at ¾ load it will drop to 77 per cent power factor, at ½ load it will drop to 62 per cent power factor, at ¼ load it will drop to 38 per cent power factor. Inasmuch, as the per cent magnetizing current generally increases with decrease of rated speed and with decrease of h. p. rating, it is at once evident that the small induction motor which forms such a large proportion of total connected motor load, is probably one of the most vicious of the species. This is due not only to the fact of the inherent low power factor at full load; but more particularly to the fact that due to its small size; its installation is given very little engineering consideration and capacities are frequently poorly selected.

This general condition has proved of sufficient practical importance to power companies to have resulted in certain of them in the cotton and woolen mill districts of New England accepting the responsibility of checking the customer's motor installations in this respect. The result of these investigations has generally been a more or less extensive overhauling by the customer of his motor installation for the purpose of operating all motors at better load factors, with resultant improvement in power factor highly satisfactory to both parties.

The power company is able, by the change, to furnish better voltage regulation at the same load, and with diminished losses, or handle an increased power load over the transforme and distribution lines at no increased cost for gen..ating equipment,

transformers or distribution copper; while the customer finds himself with an improved drive and generally a few idle motors on hand, for emergency service or extension purposes, which were previously tied up on his lines.

Activities in the industrial field which result as plainly in mutual good are highly inviting in these days of intensified group strife.

The Transformer and Power Factor

The same bill of complaint can be brought against the transformer though in a lesser degree, for this appliance also takes a constant lagging magnetizing kv-a. at a given voltage; but its magnitude is smaller than with the induction motor, varying from 1 to 15 per cent of full load kv-a. as the higher percentage values of magnetizing current in general appear in power transformers, this larger lagging kv-a. in general is added to the over-abundance already being taken by the induction motors comprising the power load.

That this magnetizing kv-a. of transformers is not entirely negligible in extreme cases may be seen from the following:

A transformer with 15 per cent magnetizing current, carrying normal secondary load at unity power factor would take primary power at approximately 95 per cent power factor which would drop to 90 per cent power factor if its secondary load were reduced to one-half normal and to 84 per cent power factor if it were again reduced to one quarter normal.

Effect of Over-Voltage on Power Factor of Induction Motor

Even the values of magnetizing current just given for induction motors and transformers may be materially increased with the raising of the applied voltage above that for which the appliance is rated.

Since induction motors when run at 10 per cent over-voltage may easily take a magnetizing current 20 to 25 per cent in excess of that required, at normal voltage, it is evident that it is possible to find conditions where the disturbing effect of induction motors on power factor may even be much in excess of that previously delineated.

Over-Voltage on Transformer in Relation to Power Factor

With the transformer, the application of over-voltage is even more serious than with the induction motor, in this respect, due to the lack of any air gap in its magnetic circuit.

The pole type variety of this appliance, which is generally forgotten after once installed, and considered to be operating satisfactorily unless emitting smoke, though designed for low iron losses, will often sustain a 50 per cent increase of magnetizing current at 10 per cent over-voltage which amounts to 55 per cent increase in lagging kv-a. taken by the appliance.

The power transformer of larger size such as typically used for handling industrial customers who are supplied on separate feeders, or such as are installed in the power company's substation for reducing the higher distribution voltage to that of the substations feeder bus, is a much more serious offender than the pole type in matters of the above nature. Not only do they take a larger percentage exciting current at normal voltage due to the fact that they are expected to operate at better load factor than transformers of the pole type, and, therefore, iron and copper losses are more nearly equalized; but also sustain a greater increase in this current with increase of voltage. In fact the magnetizing current may frequently double with 10 per cent increase in voltage above normal, making the statements previously given on basis of normal voltage conditions much too conservative. It becomes apparent, therefore, that in some cases, transformers also can make themselves distinctly felt as destroyers of good power factor conditions.

Miscellaneous Sources of Bad Power Factor

Besides of these causes of trouble, there must also be mentioned certain more specialized types of electrical appliances which inherently produce a low power factor load of which the bad power factor can only be corrected for, not provided against. Common examples of these types are electric welding machines, arc furnaces and some types of heating appliances.

The problem here, however, is a localized one of special nature, rather than a general condition and should be handled on that basis.

A more unusual and unique condition is that occasionally found in systems where the transmission network is very highly extended in proportion to load carried by it, with the result that the capacity current taken by the lines is so large in proportion to the load current that bad power factor means a leading power factor and an induction motor becomes a corrective device. Such cases are not hypothetical, for there comes to mind such a system in the Middle West adjacent to one of the standard lagging power factor characteristics where considerable consideration has been given to interconnection whereby each would act as a power factor corrective device for the other.

Synchronous Motor in General As A Remedy for Bad Power Factor

In eliminating bad power factor at its source, a most valuable ally is the synchronous motor. This device has been on the market for twenty years or more; but until recently was considered so limited in its application, both on account of its torque characteristics and greater trouble in starting, due to the necessity of switching on field and synchronizing, which were wont to be considered as delicate operations; that it is probable that less than 5 per cent of the motor horse power in this country today is of synchronous variety.

Recently this motor has begun to come into its own

due to steady improvement in its design characteristics and simplification of starting equipment, and also to increasing familiarity of operating public with this type of device. Slowly this motor has enlarged its usefulness until it now may properly be given consideration on any constant speed application which can be handled by an induction motor.

The fact that the synchronous motor has actually been applied with good results to the drive of compressors, grinders, stone crushers, pumps, both centrifugal and plunger blowers, steel and copper rolls, cement and rubber mills, flour mill rolls and line shafting in general, is concrete evidence of the fact that this motor has already covered a wide field in its application.

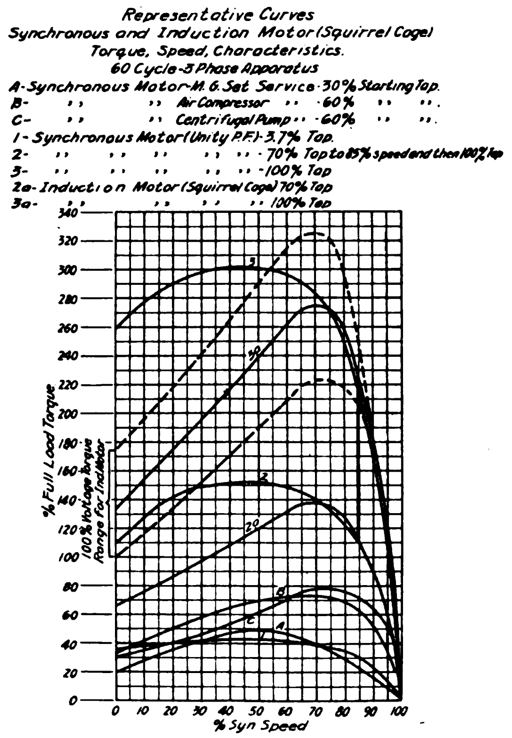

FIG. 3

UNITY POWER FACTOR SYNCHRONOUS MOTOR

When operated without capacity for over-excitation of its field, this device takes energy at unity power factor and even then, in a real sense, is a power factor corrective device, for it relieves the system of the lagging kv-a. that would have been added by the induction motor and thus by the substitution, really furnishes corrective kv-a. to the system of probably 30 per cent of its normal rating.

Synchronous motors of this particular type have recently become available in a consecutive line over approximate range from 50 h.p. at 1200 rev. per min. to 450 h.p. at 600 rev. per min. specifically designed to invade as far as possible, the field of motor application now held by the induction motor, with representative results for particular ratings which are very encouraging, as to the future of the device.

Referring to Fig. 3 and 4 giving comparative representative torque-speed and kv-a. input-speed curves respectively for standard synchronous motors, induction motors and unity power factor synchronous motors above mentioned, it may be interesting to note that with about 60 per cent as much kv-a. the unity power factor synchronous motor will easily duplicate the starting torque characteristics of the standard synchronous machine for motor generator set service. Comparative inspection of curves 2 and 2A giving relative torque characteristics of unity power factor synchronous and squirrel-cage induction motors when operated from 70 per cent voltage tap reveals the fact that the synchronous motor up to about 85 per cent speed delivers well above full load torque and from kv-a. input curve 2 it is evident that maximum input is approximately only 3½ times normal kv-a. At

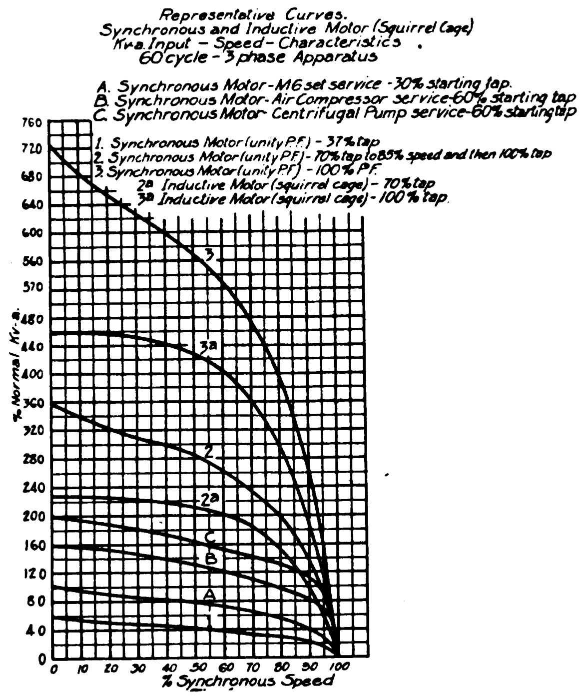

FIG. 4

speeds above 85 per cent the torque characteristics of these two types are very similar. It is also entirely feasible at the 100 per cent torque, 85 per cent speed condition to throw full voltage on the synchronous motor when it would pass over to full voltage characteristic and again take a maximum of about 3½ times normal kv-a. and develop a torque which would not drop to the normal full load value until 95 per cent speed were reached. From 95 per cent speed and full torque condition it would then pull into step, by application of the field. In other words, this last fact means that with motor at full torque load and synchronous speed the field could be removed and motor would drop to 95 per cent speed only and again pull into step with reapplication of the field. It is clear also from full voltage curves, that the maximum torque of this type of synchronous motor is entirely comparable with that of squirrel cage induction types.

Nevertheless it must not be considered that such a motor will handle any application on which the induction motor, even of squirrel-cage design, can; for as a general thing the squirrel-cage induction motor will develop the comparative starting torque for a much longer time with the same temperature rise in the squirrel cage winding, than will the synchronous competitor. Therefore, when the total amount of momentum to be stored up in rotating mass of the driven appliance, during starting cycle, is very large, it is possible to exceed the safe temperature limits of the starting winding in the synchronous machine.

This class of load is apt to trouble even the squirrel-cage motor and, by the conservative, would be assigned to the field of the wound-rotor induction motor, which by proper selection of external resistance can be arranged to give maximum torque at any speed up to full torque speed and, due to considerable heating being in grids, external to machine, has capacity for maintaining large torque for comparatively long periods of time.

Since the wound-rotor induction motor, due to higher cost, is generally reserved for installations with exceptional starting duty requirements, or speed variation capacity, it is not so general in its use and comparative in its duty, as is the squirrel cage type. Due to this, in conjunction with the fact that the torque-speed-input-speed characteristics are functions of the starting resistance and result in an infinite series of curves to cover all possibilities, no attempt has been made to include the wound-rotor induction motor in the detailed comparison, though in some applications, even this device can be supplanted by the synchronous machine.

It is evident, therefore, that considerable relief from the extension of the bad power factor in the future, should be obtained by the increased use of the unity power factor synchronous at the expense of the induction motor. This method of treatment is especially advantageous as it eliminates the lagging kv-a. of the induction motor that would have existed instead of correcting it after it has been added.

Phase Modifier as a Power Factor Corrective Device

Another method of bad power factor elimination which is better known in European practises than with us, is the use of the phase modifier. This scheme is practically that of furnishing an exciting voltage of proper magnitude, frequency and phase relation to the rings of the wound rotor induction motor, the power factor of which it is purposed to raise. The limitations of this device from an engineering standpoint are due to the facts:

(1) That it is impractical to use with a motor which is frequently started.

(2) That the amount of correction is dependent upon the design and also load on the induction motor, is unsusceptible of variation at will, is practically limited by relative cost of modifier to corrective necessary to bring the induction motor load to unity or less.

(3) That it is not operative without the induction motor.

(4) That it is applicable only to constant speed, non-reversable, wound-rotor induction motor.

(5) and finally that the scheme necessitates an additional machine either driven separately or by the induction motor.

The commercial possibilities of the device lie in offsetting the cost of the additional machine, by the saving in cost of the induction motor designed for high iron densities and resultant high magnetizing current, and by the capitalization of the increase in power factor obtained by modifier over what would have been obtained from standard designed induction motor. The fact that the standardized factory production methods of the country make it very difficult to lower induction motor costs by deviation from standard design, may possibly account for the limited exploitation of this method of power factor correction within our own field.

Over-Excited Synchronous Motor as Corrective Agency

With the application of the synchronous motor, with ability for over-excitation to a system, corrective capacity can be obtained for bad power factor conditions already existing in amounts variable at will up to the limits of the machine and in a very economical way. This fact is evident when it is remembered that the additional corrective kv-a. of the motor does not add directly to the load kv-a. with the result for example, that a motor having a rating of 80 kv-a. at unity power factor would have a rating of only 100 kv-a. at 80 per cent leading and yet would add to itself a power factor corrective capacity of 60 kv-a. That is to say, by increasing the machine rating 25 per cent above unity power factor rating, a corrective capacity is obtained equal to 75 per cent of the original rating of the machine.

Wherever, therefore, it can be arranged to use a synchronous motor for power purposes, it can be selected to furnish a considerable amount of corrective kv-a. at a very low first cost and operating expense, as the major portion of both is chargeable to the power load.

A notable example of the application of this principle is found in the use of the synchronous motor-generator set in the substation. Where there is a combined demand for direct current, generally for traction purposes, and for a-c. energy localized around one substation, it is very convenient to obtain the direct current from the generator of a motor-generator set and power factor correction for a-c. load from synchronous motor of the same set.

Although the 60-cycle railway converter both as a

normally and automatically operated device is on firm ground as a satisfactory piece of electrical equipment, the motor-generator set on account of relatively large capacity for power factor correction is a very active competitor of the synchronous converter in many cases and lends itself admirably to any demand for automatic control.

Synchronous Condenser as a Power Factor Corrective Appliance

When the demand for over-excitation on a synchronous motor is pushed to the limit and becomes entirely dominant in the design, we have the synchronous condenser, which is a motor to the extent only of revolving itself and a provider of leading corrective kv-a. to practically its total rating.

The adaptability of this machine is very high as can be illustrated by the fact that it is made in voltages from 220 or below to 13,000 volts or better in sizes from approximately 100 to above 30,000 kv-a.

The secondary effect of the variation of voltage drop, due to changes in power factor, has so often been made use of in connection with the synchronous condenser, that it is often used primarily as a voltage regulator. It lends itself admirably to this purpose as the excitation of the condenser can be automatically controlled so that by thus varying the power factor of the line, constant voltage can be held within the limits of the capacity of the machine. The condenser may even be arranged to place itself on the line and take itself off again as need for it is evidenced by the value of the line voltage; or even as determined by the dictates of a time clock.

The disadvantage of synchronous condensers lie in the fact that there is no power output which can be called upon to share the cost and operating expense with the power factor corrective capacity and these factors therefore, mount rapidly as compared with the synchronous motor situation. As a power factor corrective device only, it is, however, easily the leader in general usefulness and without it large problems of a-c. distribution and transmission would be difficult of solution.

Static Condenser

One of the newer agencies for power factor correction which overlaps in its field of application, the low capacity end of synchronous condenser territory, is the static condenser which is nothing more than the commercial application of the "Leyden Jar" to the problem of power factor correction.

As compared with the synchronous condenser, it has the following disadvantages:

(1) Is practically of fixed capacity as operated.

(2) Corrective capacity is leading only, not leading or lagging as desired, as with synchronous condenser.

(3) Takes more floor space per kv-a.

(4) In large sizes costs more per kv-a.

These shortcomings far from remove its usefulness, as it has the following outstanding qualities of merit.

(1) Very low losses (1 to 2½ per cent, while synchronous condenser losses vary from approximately 10 per cent to 3 per cent with increase of size).

(2) No rotating parts, therefore, no lubrication costs. no bearing wear and no noise.

(3) Less attendance.

(4) Easier to put on or take off line—accomplished simply by closing or opening an oil circuit breaker.

(5) Operates at low temperature rise and, therefore, does not heat up operating room as much as a synchronous condenser.

The limits of the field of application of this type of apparatus in competing with the synchronous condenser, are for practical purpose those of economic balance and not those of design, for the static condenser can be furnished in any capacity by continued multiplying of condenser sections. The practical usefulness of the static condenser can be best exemplified by the fact that there is today in process of manufacture a total kv-a. capacity, equal to the total capacity produced over the whole eight or nine-year period of its manufacture.

Power Factor Corrective Engineering

Having arrived at the conviction that power factor correction is generally a thing to be attempted it might be worth while to point out that the sane way to go about it is:

First—To locate its causes.

Second—Remove the causes insofar as practical.

Third—If correction is still needed, install corrective devices as near the source of bad power factor as possible, limited by the economic fact that power factor corrective devices cost more per kv-a. in small units.

The limit to which correction should be carried may be arbitrarily set:

(1) By voltage regulation requirements.

(2) By balance of yearly value of savings against yearly cost of correction.

(3) By economic balance as described under (2) supplemented by power factor penalties and bonuses (one or both) in power rate.

(4) By necessity of carrying more power over available distribution lines irrespective of economic balance.

(5) Or even, by condition that has recently risen in the East, when for lack of available power, customers were limited by power companies to a certain kv-a. demand. In such a case, it was found advisable for certain customers to correct the power factor absolutely up to unity, so critical was the need for the additional power. The urgency of the case can be better appreciated when it is remembered that for addition of say 10 per cent of load kv-a. in power factor corrective kv-a. to load, with an initial power factor of 70 per cent

the reduction in load kv-a. would be about 7½ per cent of original kv-a. load. By addition of successive amounts of corrective kv-a., 10 per cent addition at 80 per cent power factor condition would reduce kv-a. by about 5½ per cent of original kv-a., and last 10 per cent necessary to bring load up to unity power factor would effect a reduction in load kv-a. of only 8/10 of one per cent of original kv-a.

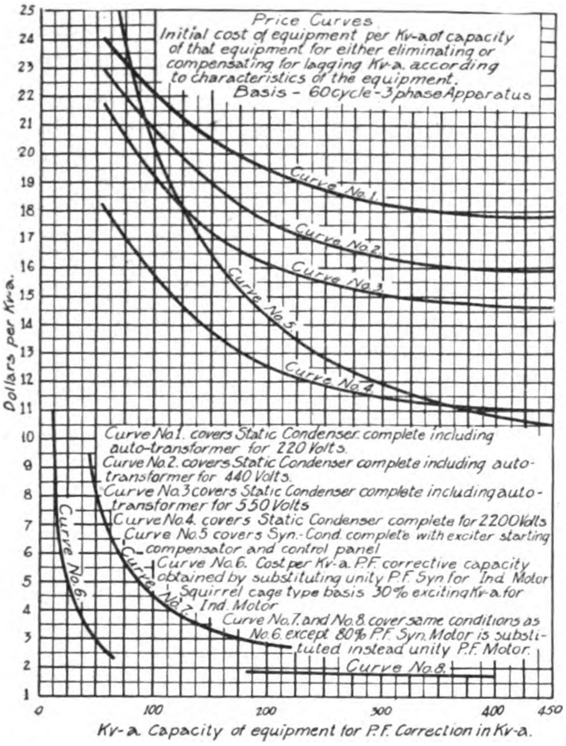

Fig. 5

Analysis of the Cost of Different Power Factor Corrective Devices

The final question in this situation is sure to be, "what will it cost?" and some general facts on this may be fittingly considered.

Referring to Fig. 5 for approximate information on 60-cycle motor prices—curve No. 1 gives price per horse power of 80 per cent power factor synchronous motor complete with exciter and starting equipment in capacities ranging from 50 h.p., 1200 rev. per min. to 450 h.p., 300 rev. per min.

Curve No. 2 furnishes equivalent information on wound-rotor type of induction motor complete with starting equipment in sizes 50 h.p., 1200 rev. per min. to 250 h.p., 600 rev. per min. and continues in curve No. 5 over a range from 250 h.p., 450 rev. per min. to 450 h.p., 300 rev. per min.

Curve No. 3 covers the unity power factor synchronous motor complete with exciter and starting equipment, over range from 50 h.p. and 1200 rev. per min. to 450 h.p. and 300 rev. per min.

Curve No. 4 represents prices of induction motor, of squirrel cage variety complete with starting equipment, in ratings from 50 h.p., 1200 rev. per min. to 250 h.p., 600 rev. per min. which continues in curve No. 6 over range from 200 h.p., 450 rev. per min to 450 h.p., 300 rev. per min.

Using the above price curves as a basis supplemented by assumption of 30 per cent exciting kv-a. for induction motors throughout, we have Fig. 6 on which curve No. 1 represents the power factor corrective kv-a. that would be added to systems by substitution of a unity power factor synchronous motor for induction motor of same rating, plotted against the motor rating.

Curve No. 3 represents the power factor corrective kv-a. obtained by similar substitution of 80 per cent leading power factor synchronous motor.

Curve No. 2 shows price per kv-a. of power factor corrective capacity obtained against the size of each of the two motors wherein substitution was made in case where unity power factor synchronous motor was used as a substitute for squirrel cage induction motor, while curve No. 4 gives equivalent information in case 80 per cent power factor leading synchronous motor were substituted.

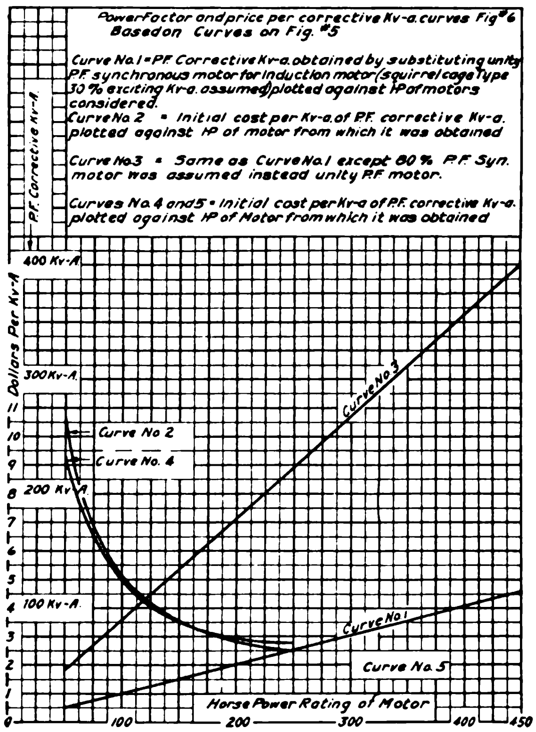

Fig. 6

Curve No. 5 continues the comparison over a range from 250 h.p. at 450 rev. per min. to 450 h.p. at 300 rev. per min.

The comparison fails in this range for unity power factor size motor, as it probably will not cost more than the induction motor of squirrel cage type.

The interesting fact becomes evident that in case either substitution is practised the price per power factor corrective kv-a. obtained is about the same for a given motor size although of course the total amount

obtained is approximately three times as much with 80 per cent power factor motor as with unity power factor variety. The choice of type of synchronous motor will therefore be made on the basis of relative characteristics and amount of corrective kv-a. desired.

In Fig. 7, we have a comparison of price per kv-a. of obtaining power factor corrective kv-a. by the several methods.

Curves 1, 2, 3 and 4 give price per kv-a. of static condensers complete for voltages of 220, 440, 550 and 2200 respectively; the variation in price being accounted for by the fact that the condenser voltage in 200, 440 and 550-volt instances is reduced by an auto-transformer to meet rated voltage, and the greater the reduction, the greater the auto-transformer price per kv-a. of static condenser.

Curve No. 5 represents the price per kv-a. for 60-cycle, three-phase size condenser complete with exciter

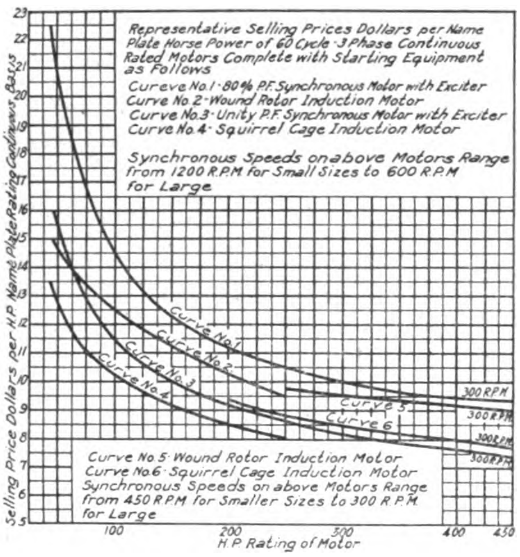

Fig. 7

and starting equipment and it should be noted that for small sizes even the initial investment is less for the static condenser.

Curve No. 6 shows price per power factor corrective kv-a. obtained by substituting unity power factor synchronous for squirrel cage induction motor, plotted against the amount obtained over the range of motors 50 h.p. to 250 h. p. giving a maximum of approximately 65 kv-a.

Curve No. 7 brings out the cost per power factor corrective kv-a. obtained by substitution of 80 per cent power factor synchronous motor for squirrel cage induction motor over range 50 h.p., 1200 rev. per min. to 250 h. p., 600 rev. per min. giving a maximum of about 223 kv-a., and curve No. 8 continues this information over motor range from 200 h.p., 450 rev. per min. to 450 h. p., 300 rev. per min. reaching a maximum available power factor corrective kv-a. of approximately 400.

A casual observation of these curves should convince one of the advisability of using the substitution method of obtaining power factor corrective kv-a. to the extent that it is possible of application.

The limitations of the substitution method are obviously due to necessity of disposing of replaced induction motor at no loss to comply with the assumptions. In case of new installations, this is entirely applicable; in other cases, the prices given must be increased to cover loss, if any, on replaced motor.

The difference between curves No. 6 and No. 7 should not be misconstrued. From curves it would seem that a cheaper way to obtain given corrective kv-a. can be found with the use of unity power factor motor in substitution game, than by the use of 80 per cent power factor type. It should be remembered that to get the same amount of correction as can be obtained by substituting a 100-h.p. 80 per cent power factor synchronous motor for a squirrel cage induction motor, it would be necessary to substitute a unity power factor synchronous motor for an induction motor of about 350-h.p. rating. As the cost per

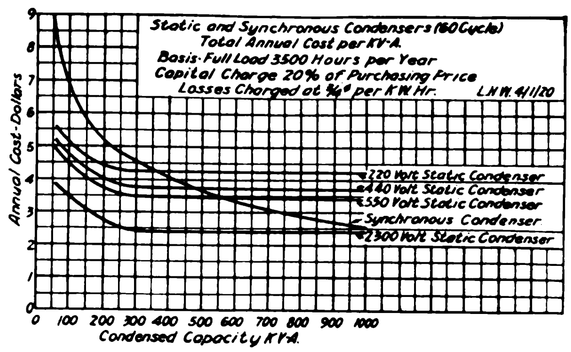

Fig. 8

corrective kv-a. goes down with increase in size of motors considered, it is seen that the conditions above stated are not justly comparable. It is much better to remember that for a certain motor in question to be substituted the price per corrective kv-a. obtained with either type of synchronous motor is about the same but the amount is greater with the 80 per cent power factor type.

There has been no attempt to include the capitalization of the difference in efficiencies of the two general types, *viz.* synchronous and induction motors. It is probable that the synchronous variety would have the better of it by 1 to 2 per cent at full load and add something more to the reasons for the change.

When no more relief can be obtained in the battle against bad power factor by procedure above outlined, the synchronous and static condenser become the logical subjects for consideration.

Here the relative efficiencies are at so great a variance that an analysis on the basis of yearly expense composed of capital charge, to cover interest on purchase price of apparatus and depreciation of same, plus losses at a price per kw-hr. must be made.

Referring to Fig. 8 will be found such a comparison

for synchronous and static condensers over rating from 60 to 1000 kv-a. and standard voltages of 220, 440, 550 and 2200 volts. Each equipment is charged in each respective capacity with 20 per cent of first cost, as capital charge per year and to this has been added the losses on basis of full load operation for 3500 hours per year at ¾ cents per kw-hr.

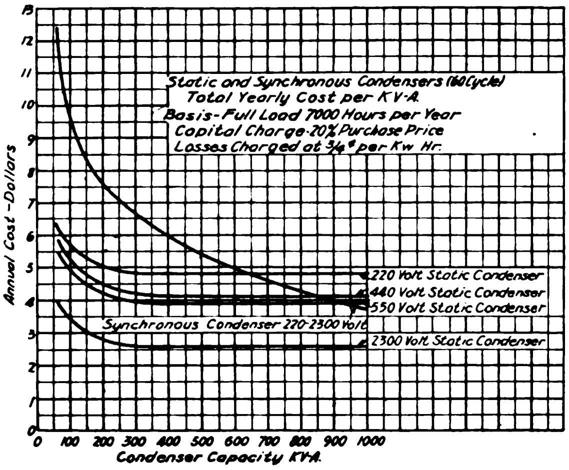

Fig. 9

On this basis it will be noticed that the static condenser in lower voltages is the cheaper device to own and operate in sizes approximately 500 kv-a. and below, and in case of 2200-volt apparatus the static device maintains its superiority up to capacities of about 1000 kv-a. If it were more reasonable to assume 24 hours per day operation on all days except Sundays and holidays as an equivalent basis of comparison and leave other assumptions untouched, results will be obtained as shown in Fig. 9 when the range of superiority of the static condensers may be said to have been increased 50 per cent making thereby the static device cheaper, in lower voltages in capacities of 750 kv-a. and below, and at 2200 volts in capacities well above the 1000-kv-a. rating.

Thus for cases where the condenser capacity is needed in amounts of approximately 750 kv-a. or less with a certainty of pretty constant operation and no demand for automatic voltage control, it is well to remember the static condenser as a worthy competitor of the synchronous device.

Conclusion

There is right now a peculiar pertinence to a review of a field so full of possibilities of reduction in delivered cost of electric power. Civilization's hope of the future lies in man's growing ability to produce per unit of time with resultant reduction of cost in terms of unit wage. Man's greatest aids in this battle are machines and power; which is growingly electric power.

Thus the delivered cost of electric power is becoming incorporated more and more widely into the cost of the necessities of life which is making the cost of electric energy a question of universal interest, and the engineer, if he maintains his expected measure of usefulness, must analyse his power producing and distributing plant today as never before, with the hope of new savings not only for his own and employer's good, but for general good as well.

It is hoped that the foregoing general facts may be fruitful to you in ideas which may aid in the broad problem before us all.

WHY THE CIVIL SERVICE COMMISSION STILL SEEKS APPLICANTS

Comment indicating wonder has been made in the press and elsewhere from time to time that the United States Civil Service Commission is still seeking applicants for examinations, notwithstanding the fact that the war is over and the Government force is decreasing. The Commission wishes to make clear its position in this matter.

On April 1, 1917, about 500,000 persons were employed in the Federal executive civil service. On November 11, 1918, the date of the signing of the armistice, at the height of the war expansion, this force had increased to about 850,000. It has now been reduced to about 650,000, and further reductions are steadily being made.

Although the Government force is constantly diminishing, the Commission must still seek applicants for some positions. The natural "turnover" in a force so large requires some appointments to fill vacancies, even though the total force is reducing. Fully three-fourths of all appointments are now made from "re-employment registers," which are made up of the names of employees dismissed because of reduction of force.

There are two conditions which necessitate some new appointments and, therefore, some announcements of examinations. One of these is that there are a number of technical positions to be filled from time to time for which re-employment registers do not provide eligibles. Because some offices are dismissing clerks, that fact does not help the Commission in its effort to fill a position of civil engineer, for example. The other reason is that the salaries now offered by the Government in the clerical grades are in many cases unattractive and dismissed employees decline to accept them and return to their homes. This leaves the re-employment registers not equal to the calls of the departments.

The Commission hopes that it may have the continued cooperation of the press in its effort to keep the Federal civil service up to a high standard of efficiency.

Alignment Chart For Circular and Hyperbolic Functions of a Complex Argument in Rectangular Coordinates

BY V. BUSH
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Explanatory Note

THIS chart is based on the expansion formula:

$\sinh(x \pm j\,y) = \sinh x \cos y \pm j \cosh x \sin y.$

The two parts of the resulting expansion readily lend themselves to solution by an Alignment Chart. Thus Scale B is plotted to log. sinh x, and numbers used for grading are actual values of x. In the same way, Scale C is plotted to log. cos y, and numbers used for grading are actual values of y. The Scale E is plotted to the logs. of the products of Scales B and C, and the numbers these logs. represent are used for grading.

Thus any line drawn from x on Scale B to y on Scale C will intercept the value of $\sinh x \cos y$ on Scale E. In the same way, any line drawn between x on Scale A and y on Scale D will intercept the value of $\cosh x \sin y$ on Scale E. The first value plus or minus j times the second value gives the actual value of $\sinh(x \pm j\,y)$.

The values of y are given in quadrants, since it greatly facilitates the use of the chart. This must be remembered in handling functions and if the circular or imaginary power is expressed in radians, it must be reduced to quadrants for use in the chart, which can easily be done by multiplying by $\frac{2}{\pi}$.

By means of the expansion formulas, a very great variety and range of functions can easily be evaluated. For example:

$$\sinh 4\underline{/30^\circ} = \sinh(3.46 + j\,2) \text{ (in radians)}$$
$$= \sinh(3.46 + j\,.1275) \text{ (quadrants)}$$

Line from 3.46 on Scale B to 0.1275 on Scale C gives 16 on Scale E.

Line from 3.46 on Scale A to 0.1275 on Scale D gives 3.2 on Scale E.

Value of function is thus $16 + j\,3.2$, or:

$$\sinh 4\underline{/30^\circ} = 16 + j\,3.2$$

Value from tables: $15.8 + j\,3.15$, which checks well with this chart.

Formulas

$$\sinh(x \pm j\,y) = \sinh x \cos y \pm j \cosh x \sin y$$
$$\cosh(x \pm j\,y) = \cosh x \cos y \pm j \sinh x \sin y$$
$$\sin(x \pm j\,y) = \sin x \cosh y \pm j \cos x \sinh y$$
$$\cos(x \pm j\,y) = \cos x \cosh y \mp j \sin x \sinh y$$

Quadrant Formulas

e is an even integer, n is an odd integer

$$\sinh\{x + j(y \pm e)\} = -\sinh(x + jy)$$
$$\cosh\{x + j(y \pm e)\} = -\cosh(x + j\,y)$$
$$\sinh\{x + j(y \pm n)\} = +j\cosh(x \pm j\,y)$$
$$\cosh\{x + j(y \pm n)\} = +j\sinh(x \pm j\,y)$$
$$\sinh\{x + j(y + 1)\} = -j\cosh(x + j\,y)$$
$$\cosh\{x + j(y + 1)\} = -j\sinh(x + j\,y)$$

Directions

To find: $u + j\,v = \sinh(x + j\,y)$

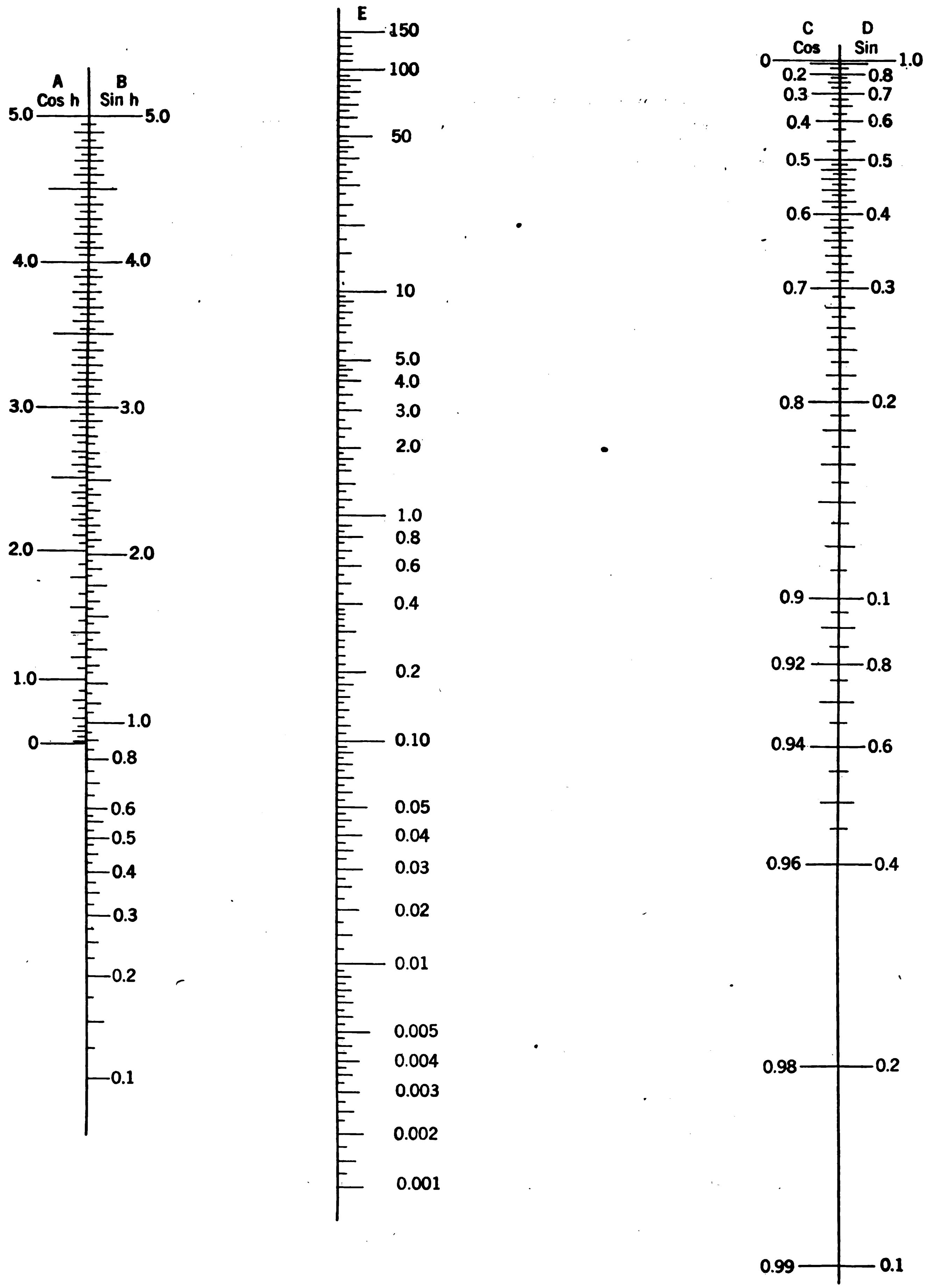
1. Express y in decimal parts of a quadrant.
2. Connect x on Scale B with y on Scale C by straight line. At intersection of this line with Scale E, read u.
3. Connect x on Scale A with y on scale C by straight line. At intersection on E, read v.

Similarly for other functions.

	u	v
sinh	$B\,C$	$A\,D$
cosh	$A\,C$	$B\,D$
sin	$D\,A$	$C\,B$
cos	$C\,A$	$D\,B$

THE TRANSMISSION OF MUSIC BY RADIO

Music can be transmitted by wireless in the same manner as speech or code signals. As an incidental result of research work on radio telephony at the Bureau of Standards, it has been shown that music can be transmitted by radio without loss of quality. The possibilities in this direction are great and very interesting. By this means a concert given in one place may be available to those living at a distance. Experimental concerts are at present being sent out on Friday evening from 8:30 to 11, by the Radio Laboratory of the Bureau of Standards, using a wave length of 500 meters. One way of transmitting music has been to place a phonograph so that the sound from it will pass into the radio transmitter. The Bureau of Standards has made an interesting improvement upon this method, which consists of substituting the carbon microphone, which is the mouthpiece of an ordinary telephone, for the vibrating diaphragm ordinarily used on the phonograph. As a result, the phonograph sound record produces direct variations of electric current in the telephone apparatus instead of producing sound, thus while no sound is heard where the phonograph record is being played, the music is easily heard by those at the distant receiving stations.



ALIGNMENT CHART FOR CIRCULAR AND HYPERBOLIC FUNCTIONS OF A COMPLEX ARGUMENT IN RECTANGULAR COORDINATES

The Design of Air-Core Inductance Coils of Minimum Weight for a Given Inductance and Resistance

BY C. O. GIBBON
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ANYONE familiar with the design of air-core inductances knows, that for a given resistance, the size and weight of the coil rapidly increase as the inductance is increased. Though the increased cost due to this increase in weight may not be of great importance, it is evident in many types of apparatus in which such coils play an essential part, as in portable radio sets, that both weight and size must be reduced to the minimum possible.

To calculate the inductance and resistance of any air-core inductance coil, given its dimensions, the size of wire, and the number of turns, is a simple matter; but to design a coil which shall have any preassigned values of resistance and inductance, with this added condition, that the coil have minimum possible weight, is a problem which ordinarily presents no little difficulty and necessitates numerous trial calculations.

Any cut and try method of design is both unsatisfactory in results and wasteful of time. It was for the purpose of determining a simple and exact procedure in the design of such coils that the writer recently carried out an analytical investigation of the problem. The results of that analysis render it possible to read directly from curves the dimensions and weight of the lightest air-core inductance coil having any specified inductance and resistance, and by the use of simple formulas, to determine at once the number of turns, manner of winding, and size of wire to be used. The theoretical derivation of these curves and formulas, together with an outline of the proper procedure in their use, in the main, form the subject of the present paper.

The General Inductance Formula

The inductance of a circular coil of rectangular cross-section (see Fig. 1) having an air-core, is given by Maxwell to be:

$$L = 4\,\pi\,a\,N^2 \left[\left(\text{logh}.\ \frac{8\,a}{R}\right) - 2\right] \text{ centimeters} \quad (1)$$

where

L = Inductance in centimeters.
N = Total number of turns in coil.
a = Mean radius of coil in centimeters (see Fig. 1)
R = Geometrical mean distance of the transverse section of the coil from itself.
logh. stands for the Naperian logarithm.

For any value of the ratio $b : c$, where b is the axial length and c is the radial depth of the coil (see Fig. 1), both in centimeters, Maxwell further shows that

$$R = k'\,(b + c) \quad (2)$$

where (k') is a constant of proportionality. Equation (1) then becomes

$$L = 4\,\pi\,a\,N^2 \left[\left(\text{logh}.\ \frac{8\,a}{k'\,(b + c)}\right) - 2\right] \text{ centimeters} \quad (3)$$

General Outline of Theory

Before entering further upon the details of the analysis it may be illuminating to outline, in a general manner, the steps to be taken.

If we assume a wire of which the length (1) and the resistance R are fixed, the cross-section of the wire, its weight, and the product $(4\,\pi\,a\,N)$ are also fixed. This wire we may wind into any circular coil of rectangular cross-section we choose: for each manner of winding a unique value of inductance will result. Our problem then resolves itself into one of determining such relations between a b and c as will, for the given wire, insure maximum possible inductance.

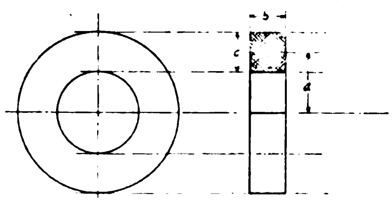

Fig. 1

The mathematical solution of this problem divides itself into the two following steps:

1. We may hold a constant, thereby fixing the number of turns N and the transverse area $b\,c$ of the coil, and determine that ratio $b : c$ which will give maximum inductance.

2. Keeping the ratio $b : c$ so obtained we may allow a to vary, thus arriving at that ratio $a : b$ for maximum inductance.

These ratios determined we may derive the curves and the auxiliary formulas necessary for the complete design.

Step 1.

As stated above our fixed values are first a, R, N and

$$b\,c = k'' \quad \text{whence } c = \frac{k''}{b} \text{ cm.}$$

also

$$4\,\pi\,a\,N^2 = K \text{ (a constant)}$$

Then

$$\text{logh}.\ \frac{8\,a}{k'\,(b + c)} = \frac{K}{b + c} = \frac{k}{b + \dfrac{k''}{b}} \text{ numeric}$$

Substituting these values into equation (3) it becomes

$$L = K\left[\left(\text{logh.}\,\frac{k}{b+\frac{k''}{b}}\right) - 2\right] \qquad \text{cm.}$$

$$= K\left[\left(\text{logh.}\,k - \text{logh.}\,b + \frac{k''}{b^2}\right) - 2\right] \qquad \text{cm.}$$

Differentiating with respect to b and equating to zero we obtain

$$\frac{dL}{db} = -K\left(\frac{1}{b+\frac{k''}{b^2}}\right)\left(1 - \frac{k''}{b^2}\right) = 0$$

or

$$\left(\frac{b}{b^2+k''}\right)\left(\frac{b^2-k''}{b^2}\right) = 0$$

Of the two factors on the left one must vanish. It is obvious that for positive values of k'' the term $\frac{b}{b^2+k''}$ vanishes only if k'' becomes infinite.

Hence we must have

$$\frac{b^2-k''}{b^2} \quad \frac{b^2-bc}{b^2} = 0$$

whence $b^2 - bc = 0$

or finally $b = c$ cm.

This tells us that the coil of minimum weight for given inductance and resistance is square in cross-section.

If $b = c$ Maxwell gives $k' = 0.2235$ and equation (3) reduces to

$$L = 4\pi a N^2\left[\left(\text{logh}17.9\,\frac{a}{b}\right) - 2\right] \quad \text{centimeters} \tag{4}$$

Step 2

Again referring back to the general outline we shall allow a to vary, while our constants are

$$4\pi a N = k_2$$

and

$$2\pi a N = k_2'$$

from which

$$N = \frac{k_2'}{2\pi a} = \frac{k_3}{a} \qquad \text{turns}$$

The size of the wire being fixed evidently necessitates that

$$b\,c = b^2 = k_5 N = \frac{k_4'}{a} \qquad \text{cm.}^2$$

or

$$b = \frac{k_4}{\sqrt{a}} \qquad \text{cm.}$$

Substituting these values into equation (4) and placing $17.9 = k_1$ it becomes

$$L = k_2\frac{k_3}{a}\left[\left(\text{logh}\,\frac{k_1 a^{3/2}}{k_4}\right) - 2\right] \qquad \text{cm.}$$

Differentiating with respect to a and equating to zero

$$\frac{dL}{da} = -\frac{k_2 k_3}{a^2}\left[\left(\text{logh}\,\frac{k_1 a^{3/2}}{k_4}\right) - 2\right]$$

$$+ \frac{k_2 k_3}{a}\left(\frac{k_4}{k_1 a^{3/2}}\cdot\frac{k_1}{k_4}\cdot a^{1/2}\right)\frac{3}{2} = 0$$

$$\text{logh}\,\frac{k_1 a^{3/2}}{k_4} - 3.5 = 0$$

$$\frac{k_1 a^{3/2}}{k_4} = \frac{k_1 a^{3/2}}{b\,a^{1/2}} = k_1\,\frac{a}{b} = \epsilon^{3.5} \qquad \text{numeric}$$

from which $a = 1.85\,b$ cm.

Substituting this relation into equation (4) it reduces to our final formula

$$\left.\begin{array}{lll} & L = 18.85\,N^2 a & \text{centimeters} \\ \text{when} & b = c & \text{centimeters} \\ \text{and} & a = 1.85\,b & \text{centimeters}\end{array}\right\} \tag{5}$$

The writer up to this point has merely retraced a path long ago explored by Maxwell (see "Electricitiy and Magnetism," Vol. II, pp. 345-346, p. 706) who has already pointed out the preceding relations between a, b and c. These relations, however, have been here derived in a manner much more easily grasped, and with far more detailed steps than in their treatment in the classic work of Maxwell. The derivation is therefore given for the sake of its simplicity and for the clearness and completeness of the paper as a whole.

But while the relations in (5) are not new, I now propose to point out and derive a series of relations which, combined with the above are developed into a system of design that to the best of my knowledge is entirely original.

Derivation of Auxiliary Formulas

With these, our fundamental relations, in mind we may consider a as the independent variable, and allow it to assume any other value $a' = n\,a$ while the inductance L is held constant, the other variables will be seen to change according to the following governing relations:

$$\left.\begin{array}{ll} \text{if} & a' = n\,a \\ \text{then} & b' = n\,b \\ & c' = n\,c \\ & L' = L \\ & d' = n^{3/2} d \\ & A' = n^{3/2} A \\ & R' = \dfrac{R}{n^2} \\ & \gamma' = \dfrac{\gamma}{n^{3/2}} \\ & W' = n^3 W \end{array}\right\} \text{Relations for constant inductance } L \text{ but variable mean radius } a. \tag{7}$$

If on the other hand we treat L as the independent variable but hold a constant then:

$$\left.\begin{array}{lll} \text{if} & L' & = m\,L \\ \text{then} & a' & = a \\ & b' & = b \\ & c' & = c \\ & N' & = N\sqrt{m} \\ & l' & = l\sqrt{m} \\ & d' & = \dfrac{d}{m^{1/4}} \\ & A' & = \dfrac{A}{\sqrt{m}} \\ & R' & = m\,R \end{array}\right\} \begin{array}{l}\text{Relations for constant} \\ \text{mean radius } a \text{ but variable} \\ \text{inductance } L.\end{array} \quad (8)$$

Where a = Mean radius of coil in centimeters.
b = Axial length of coil in centimeters.
c = Radial depth of coil in centimeters.
n and m = any multiplier.
d = Diameter of wire (bare copper) in centimeters.
A = Cross-section of wire in circular micrometers.
R = Total d-c. resistance of coil in ohms.
L = Inductance of coil in centimeters.
N = Total number of turns in coil.
γ = Resistance of wire per centimeter.
l = Total length of wire in centimeters.
W = Total weight of coil (copper) in pounds.

Of particular immediate importance are the two relations of (**8**)

$$L' = m\,L$$
and
$$R' = m\,R$$

Dividing, we have

$$\frac{L'}{R'} = \frac{m\,L}{m\,R} = \frac{L}{R}$$

That is, for constant mean radius a the resistance varies directly as the inductance, or the ratio for any given mean radius is fixed and is a function of a

$$\frac{L}{R} = K\,(a)$$

If now, a is allowed to vary while L remains constant, then from (**7**)

$$K\,(a') = \frac{L'}{R'} = \frac{L}{R}\,n^2 = n^2\,K\,(a) \qquad (\mathbf{10})$$

If we assume $a = 1$
then since $a' = n\,a$
we have $a' = n$
whence $K\,(a') = a'^2\,K\,(l)$
or dropping the primes $K\,(a) = a^2\,K\,(l)$ (**11**)

Let us now calculate $K\,(l)$.

If $a_1 = 1$ cm. then $b_1 = c_1 = 0.541$ cm.
Take $L_1 = 1$ millihenry $= 10^6$ centimeters, and solve for (R).

By equation (**5**)

$$N_1 = \sqrt{\frac{L_1\,(\text{cm})}{18.85\,a_1}} = \sqrt{\frac{10^6}{18.85}} = 230.5 \text{ turns}$$

The number of turns per layer η_1 is, since $b = c$

$$\eta_1 = \sqrt{N_1} = 15.5 \text{ turns per layer}$$

The diameter of the wire d_1 is

$$d_1 = \frac{b_1}{n_1} = \frac{0.541 \times 10}{15.5} = 0.349 \text{ millimeters}$$

The resistance of copper wire at 20 deg. cent. is 228.5 ohms per circular micrometer, per centimeter length. Hence

$$R_1 = \frac{2\,\pi\,a_1\,N_1 \times 228.5}{(349)^2} = \frac{2\,\pi \times 230.5 \times 228.5}{(349)^2} = 2.715 \text{ ohms}$$

Then $K\,(l) = \dfrac{L_1}{R_1} = \dfrac{1}{2.715} = 0.368$ numeric

Whence by (**11**) $K\,(a) = 0.368\,a^2$ (**12**)

Taking the weight of copper as 0.01967 pounds per cubic centimeter, the weight of this unit will be

$$W_1 = 2\,\pi\,a_1\,b_1^2 \times 0.785 \times 0.01967$$
$$= 2\,\pi \times 0.541^2 \times 0.785 \times 0.01967 = 0.0284 \text{ lb.}$$

Here the factor 0.785 is the ratio of the area of a circle to the area of the circumscribed square and enters because we are filling a square section with circular wires.

The weight of any coil will be by (**7**)

$$W = 0.0284\,a^3 \text{ pounds} \qquad (\mathbf{13})$$

Combining equations (**12**) and (**13**) gives

$$W = 0.0284\,\frac{K\,(a)}{0.368}\,a = 0.0772\,a\,K\,(a) \text{ pounds} \qquad (\mathbf{14})$$

Curves Convenient in Design

Collecting the important relations we have

$$b = c \text{ centimeters} \qquad (\text{I})$$
$$a = 1.85\,b \text{ centimeters} \qquad (\text{II})$$
$$L = 18.85 \times 10^{-6}\,N^2\,a \text{ millihenrys} \qquad (\text{III})$$
$$\frac{L\,(\text{millihenrys})}{R\,(\text{ohms})} = K\,(a) = 0.368\,a^2 \text{ numeric} \qquad (\text{IV})$$
$$W = 0.0284\,a^3 \text{ pounds} \qquad (\text{V})$$
$$= 0.0772\,a\,K\,(a) \text{ pounds} \qquad (\text{VI})$$

Equations (IV) and (VI) enable us to plot curves from which the mean radius and weight of a coil having any assigned values of inductance and resistance may immediately be read. Such a set of curves of W and a plotted against $K\,(a)$ is shown in Fig. 2. The calculated values from which these curves were plotted are given in Table I. In using these curves it must be remembered that the values read are only approximate. The actual dimensions must be varied slightly to suit standard gage wire, and the insulation thickness must, if great accuracy is required, be taken into account.

Finally, the value of inductance should be checked by the original formula,

$$L = 4\,\pi\,a\,N^2 \left[\left(\text{logh}\,\frac{8\,a}{\mathcal{R}} \right) - 2 \right] 10^{-6} \text{ millihenrys} \tag{15}$$

in which, so long as b and c are approximately equal,

$$\mathcal{R} = 0.2235\,(b + c)$$

Procedure in Design

Having given the inductance L in millihenrys, and the resistance R in ohms, the mean radius a may at once be read off the curves, Fig. 2, or calculated by equation (IV)

$$a = 1.648 \left(\frac{L}{R} \right)^{1/3} \quad \text{centimeters}$$

Then $\quad b = c = 0.541\,a \quad$ centimeters

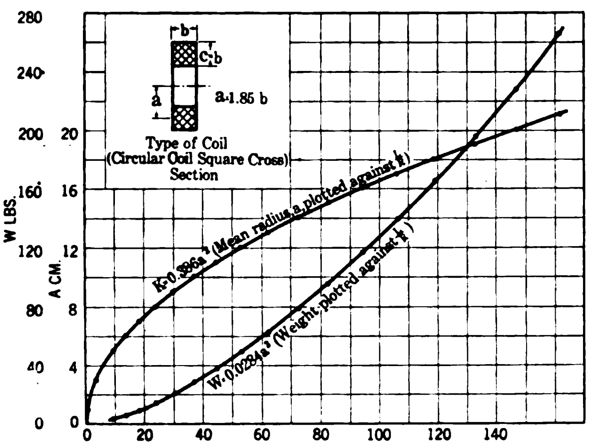

Fig. 2—Curves of Weight and of Mean Radius Plotted Against the Ratio L/R for Air-Core Coil of Minimum Weight and Maximum Inductance

Solid Copper Wire

With a and L known, next determine the number of turns from (III)

$$N = 230.3 \sqrt{\frac{L\ (\text{m. h.})}{a\ (\text{cm.})}} \quad \text{turns}$$

Since the coil is of square cross-section the number of turns per layer (V) is

$$v = \sqrt{N} \qquad \text{turns per layer}$$

The diameter d of the wire can now be found.

$$d = \frac{b}{v} \qquad \text{centimeters}$$

The weight will be given by V or may be read from the curves Fig. 2.

In general N as calculated will not be a perfect square. To meet this we may either change the cross-section of the coil slightly or vary the number of turns. Thus suppose we obtain $N = 242$ turns: the coil may be wound with 240 turns in 16 layers of 15 turns per layer. Likewise, it is improbable that d as solved will correspond to the diameter of any standard gage wire. Simply select the next larger standard gage.

Thus the complete dimensions of the coil, the number of turns, and the size of the wire have been determined by a series of simple steps, each containing but one unknown quantity. It but remains to check the inductance by equation (**15**), the resistance by the formula

$$R = a\,\pi\,a\,N\,\gamma \qquad \text{ohms} \tag{16}$$

and the solution for the coil of minimum weight for the given inductance and resistance is complete.

Coils Wound with Stranded Conductors

For the most part inductance coils are designed to operate either in alternating- or oscillating-current circuits. If the design of a coil shows that a large wire must be used, then the question of the increase of the

TABLE I

a cm.	$K = L/R = 0.368a^3$ numeric	$W = 0.0284a^3$ lbs.
1	0.37	0.03
2	1.47	0.23
3	3.31	0.77
4	5.89	1.82
5	9.20	3.55
6	13.25	6.14
7	18.04	9.75
8	23.55	14.56
9	29.80	20.70
10	36.80	28.40
11	44.50	37.90
12	53.00	49.00
13	62.20	62.40
14	72.10	78.00
15	82.80	95.80
16	94.20	116.50
17	106.30	139.60
18	119.30	165.80
19	133.00	195.00
20	147.20	227.50
21	162.20	263.00

a-c. resistance over the d-c. resistance immediately becomes important. As is well-known, this resistance ratio rises rapidly as the size of wire is increased, but may be greatly reduced by employing stranded conductor, the strands, of course, being insulated. In fact, when stranded conductor is used, if means be taken to insure an equal distribution of current in all strands, the ratio may be reduced to that corresponding to that size of wire composing the strands.

Round wires strand best in progressive squares of seven, *i. e.*, 7, 49, 2401, etc.—six conductors spiraled about one as a center in the case of seven strands, or, if 49 strands are used, seven conductors of seven strands each are made up with, say, a left hand spiraling and six of these conductors spiraled about the seventh with right hand spiraling.

If it be found necessary to use stranded conductor then, due to the space factor, the dimensions of the coil are considerably altered. The system of design which I have outlined may, by a very simple expedient, be

made to apply directly to coils wound with stranded conductor.

Suppose that a coil first wound of solid wire has a resistance R_1 and an inductance L_1. Let us now replace the solid wire with a seven-strand conductor occupying exactly the same space. The number of turns, length of conductor and dimensions of the coil will remain the same and hence the inductance will be unaltered. The resistance, however, is increased as follows. Since the diameter of each strand is one-third and the area, one-ninth that of the original solid wire, the resistance R_2 of the coil wound with such a stranded conductor will be

$$R_2 = \frac{9}{7} R_1$$

From this it is obvious that we may use for coils of stranded conductors either the curves or method of calculation given, merely by multiplying our ratio $\frac{L}{R}$ by $\frac{9}{7} = 1.286$ and proceeding as before, but basing our work on this new ratio.

For a solid wire $K_1 = \frac{L}{R}$

For seven-strand conductor $K_7 = 1.286 \frac{L}{R}$

For a 49-strand conductor $K_{49} = 1.653 \frac{L}{R}$

If desired an additional factor may be introduced to care for the space factor occasioned by the added insulation.

Control of Current Distribution among Strands

For the material in the discussion of this topic the writer is greatly indebted to Mr. D. R. Price of the Fessenden Engineering Laboratory.

It has already been mentioned that if the current in a stranded conductor be made to divide itself equally among the strands then the ratio of a-c. to d-c. resistance for the whole conductor is reduced to that of a single strand. Mere stranding, though giving better results than a solid wire, is, however, not sufficient to insure this desirable condition. Special methods must be resorted to.

Since skin effect usually becomes of importance only at frequencies above one hundred cycles, and for large wires, we need only consider the case where the reactance is many times as great as the resistance, *i. e.*, where the power component of the current is negligible compared with the reactive component.

Since the purpose of controlling the current distribution among the strands is to reduce the effective resistance, no end is served by adding resistance in series with any strand taking more than its share of current. Moreover, as the resistance drop is so small compared with the reactive drop, a resistance many times that of the strand would be necessary to produce any appreciable regulating effect. Obviously, the thing to do is to increase the inductance of any strand taking an excess of current, and to do this with as small an increase in the resistance of the strand as possible.

This may be quite simply accomplished by any one of several methods. The method which first suggests itself is to lead each strand separately to a terminal board and to connect in series with each a small independent inductance coil. These coils are then varied to equalize the current in the strands. This method is open to the objection that, since the small coils must set up their own regulating flux, a considerable number of turns may be required to produce the proper current distribution and an appreciable resistance be thereby added to that of the strand. A better method is that of tapering off the strands. That is, those strands which take an excess of current are lengthened out and given added turns about the coil itself. By this means the added turns are linked by the entire flux of the coil itself and a far greater regulating effect thus obtained with much less added resistance than by the preceding method.[1]

A Slight Digression from the Subject

In following any path of research one comes constantly upon cross-paths which enticingly tempt one to explore them and learn what point of interest may be hidden just out of sight around some turn. Thus is one often led to digress and explore a field. Since the writer takes particular pleasure in exploring these by-paths, he wandered along many such while following the research which resulted in the writing of this paper. One of these led to an interesting discovery that I shall now describe.

The coils whose design has been herein outlined may be considered coils of maximum efficiency. In many types of electrical apparatus maximum efficiency obtains when certain quantities reach equality. Thus an electric motor has maximum efficiency when its fixed and variable losses are equal. It was suggested by Prof. Reginald A. Fessenden that in these maximum efficiency coils the reluctance of the flux path through the coil should equal the reluctance of that portion of the path external to the coil.

This I verified mathematically as follows.

For the inductance of circular coils of square cross-section Weinstein has derived the formula (see Bulletin of Bureau of Standards, Vol. 5, No. 1, pp. 46 & 49).

$$L_w = L_w - \Delta_2 L \qquad \text{centimeters}$$

where

$$L_w = 4\,\pi\,a\,N^2 \left\{ \left(1 - \frac{c^2}{24\,a^2}\right)\left(\operatorname{logh} \frac{8a}{c}\right) - 0.03657\,\frac{c^2}{a^2} - 1.194914 \right\} \text{cm.}$$

1. Both of the methods here described and several others for accomplishing the same result are fully covered in patents granted to Mr. D. R. Price. See U. S. Patent No. 1,213,689.

and

$$\Delta_2 L = 4\,\pi\,a\,N \left(\text{logh} \frac{D}{d} - 0.13806 - E \right) \text{ cm.}$$

Here

N = Number of turns in coil.

a = Mean radius of coil in centimeters.

c = Length of one side of square cross-section in centimeters.

D = Diameter of covered wire.

d = Diameter of bare wire.

E = A term which takes into account the difference in the mutual inductances of the separate turns of wire on one another when the wire has a round section from what the mutual inductance would be if the wire were of square section and no space was occupied by the insulation. We shall here take E corresponding to a coil having ten layers of ten turns per layer. For this coil $E = 0.01713$ (see Bulletin of Bureau of Standards, Vol. 5, No. 1, p. 50).

For maximum efficiency coils as already shown

$$a = 1.85\,c$$

We shall take $\frac{D}{d} \doteq 1$ and $\text{logh}\frac{D}{d} = 0$ $N = 100$

Substituting these values into the above equations we find

$$L_u = 4\,\pi\,a\,N^2\,(1.54321)$$

$$\Delta_2 L = 4\,\pi\,a\,N\,(0.15519) = 4\,\pi\,a\,N^2\,(0.001552)$$

$$L = 4\,\pi\,a\,N^2\,(1.54476)$$

If

ϕ = Flux (Maxwells)

M = Magnetomotionforce (Gilberts)

$\mathcal{P}$ = Permeance (c. g. s. units)

λ = Linkages

$\mathcal{R}$ = Reluctance (Oersteads)

we have

$$\phi = M\,\mathcal{P}$$

$$\lambda = M\,\mathcal{P}\,N$$

$$M = 4\,\pi\,N\,i \quad \text{if } i \text{ is in abamperes}$$

$$\therefore \lambda = 4\,\pi\,N^2\,\mathcal{P}\,i$$

$$\frac{d\lambda}{dt} = 4\,\pi\,N^2\,\mathcal{P}\,\frac{di}{dt}$$

$$L = \frac{\frac{d\lambda}{dt}}{\frac{di}{dt}} = 4\,\pi\,N^2\,\mathcal{P}$$

$$\mathcal{P} \quad \frac{L}{4\,\pi\,N^2}.$$

That is, the permeance of the magnetic circuit of a coil equals the inductance divided by $4\,\pi\,N^2$.

Hence for the coil under consideration

$$\mathcal{P} = 1.54476\,a$$

$$\mathcal{R}_t = \frac{1}{1.544762} = \frac{0.646}{a}$$ (reluctance of total magnetic circuit)

The reluctance through the coil is

$$\mathcal{R}_i = \frac{c}{\pi\left(\frac{29-c}{2}\right)} = \frac{0.323}{a}$$

$$\frac{\mathcal{R}_i}{\mathcal{R}_t} = \frac{0.323}{0.646} = 0.5$$

Thus we have found that the reluctance of the total magnetic path is twice that of the portion of the path through the coil, or that the reluctance through the coil equals the reluctance of the remainder of the circuit, for these maximum efficiency coils.

THE PHENOMENA OF RADIO TELEGRAPHY AND TELEPHONY

Communication by means of electricity without wires has progressed very rapidly during the last few years, and has probably been given more consideration by the general public than almost any other scientific subject. It is, nevertheless, a fact that due to the somewhat inaccurate and misleading newspaper accounts which have appeared from time to time dealing with the principles of radio communication and which have been apt to surround the whole matter with an air of mystery most people believe that the principles underlying wireless transmission are not very well-known. On the contrary, radio communication is a natural effect following well-known causes. With the object of giving a concise and easily understood explanation of the principles underlying radio communication, a lecture was given at the Bureau of Standards during May of this year, in which the whole subject was thoroughly discussed in a way easily understood by all. The similarity between various forms of wave motion, of which radio communication is one, was described and illustrated. Copies of this lecture will be available for distribution to those interested.

The Study of Mentality in Industry

BY H. W. JORDAN

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THE Study of Mentality in Industry, in which the Engineering Foundation has done some preliminary work, marks a new appreciation of the responsibilities which confront us. "Civilization as we know it today is due mainly to the engineer or applied scientist. As a profession, we are largely responsible for present conditions and therefore we should do our part in solving such problems as exist, and in helping to direct aright the tendencies of the day. We have a duty to ourselves to our profession, to society, and to our successor,—and we must perform it," said George F. Swain, ex-president of the American Society of Civil Engineers.

It is a startling paradox of our times that the brain workers, the intellectual classes, who have high school education and beyond, are a decidedly minor force as citizens; while the manual workers are a powerful, swiftly growing civic force. We engineers and our associated brain workers create the industries, direct their operation and forecast their future. But as a factor in citizenship and social life, we are almost ciphers. One reason of this is that we deal with *causes*, with the foundation and substance of material and social structures. The public is not interested in a subway or in a great building under design or construction. It rarely sees these works of the engineer until the job is finished and the opening reception is held. Hence the public neither appreciates nor understands the tremendously important part which engineers play in economic and social life. The time is at hand for us to teach them.

The press, which fashions public opinion, deals with effects. The public is dazzled by sensational news, by stories of the abnormal and the gross, and by the incessant game of politics, rather than the science of government. The press deals with finished things, with effects. If a great bridge falls, the press gives it columns on the front page, but when the New York subway and the Hudson tubes carry hundreds of millions of people without the loss of a single life, that engineering achievement receives not a single line. Public opinion is based on a shaky foundation of distorted, sensational description of events, which are effects. We engineers need to build a new order of public opinion, evolved from social scientific research and based upon fundamental facts, which are causes. Our field for this public opinion is the intellectual public, the brain workers.

In marked contrast to the brain workers, there stand the manual workers of every sort. Directly and indirectly, the manual workers, to the extent of at least 35 per cent of our people, are organized and are adroitly and aggressively led along distinct lines of class purposes. By their numbers and the mere volume of their argument, they carry conviction, and secure strikes and other direct action, which prove disastrous to them and to all of us, because their efforts are directed against effects, rather than toward the discovery and scientific utilization of economic laws and natural energies. Most strikes are a mere infuriated mopping up of the floor, instead of turning off the faucet, from which the flood proceeds.

And our own action in government and in citizenship is mainly such a mad mopping up of the floor. Bernard Shaw has truly said that Americans "are the greatest post mortem nation in the world." We spend millions upon congressional, state and city "investigations," which produce little result other than to furnish front page news which is promptly forgotten.

In recent years, we have begun to learn that the life of mankind is regulated by laws as definite and knowable as the law of gravity. The century before us is destined to be one of marvelous extension in the knowledge of the mind and the application of that knowledge to social life, to government and to industry. The engineers and their industrial corporations which attain the greatest achievements in the twentieth century, will be those who most quickly learn the new sciences of the mind, and apply them promptly and effectively to engineering and to citizenship.

Hollander says: "Starting from a rude social order wherein bare and uncertain existence was the most that man could wrest from nature, society has attained an incredible economic productivity by the development of intellectual force and manual dexterity, by the more efficient arrangement of its own powers, and most of all by the discovery and utilization of natural energy." The economic era upon which we are entering, is to be characterized by similar discovery and utilization of the natural energies of the mind. The Study of Mentality in Industry by the Engineering Foundation and National Research Council, if rightly directed can be developed by the organized American engineers into an agency of prodigious benefit to the engineering industries, to government and to social life.

The work should be early extended to include subjects of international scope. In addition to specific investigations, such as those already undertaken, the study should bring the attention of American engineers to great fundamental world problems of economics, ethnology and sociology. It should be interpreted largely in terms of more efficient living, the production and distribution of food and the raw materials of clothing, the provision of adequate, comfortable housing, the maintenance of working and living conditions which assure contentment, and the expansion of the lives of brain workers into broader activity in the intellectual and spiritual fields of literature, music, art and religion. Above all else, prompt and profound attention should be given to the study of agriculture,

in its relation to industrial and social life. Equally profound thought should be devoted to racial studies, directed toward the improvement and perpetuation of the human race and the protection of the racial interests of the intellectual classes, who are now being sacrificed to industry and property. We can make a good beginning of these researches by reading Madison Grant's "The Passing of the Great Race," and Lathrop Stoddard's "The Rising Tide of Color." Our study of public opinion should include Walter Lippmann's "Liberty and the News."

The bulletins of the Foundation, which summarize these studies, should be widely distributed in pamphlet form, and should be published in all engineering and technical journals. They should then be extended to great weekly journals, like the *Saturday Evening Post*, and *Christian Herald*, *The Outlook* and similar publications which reach intellectual people. Step by step, these mental researches of the American Engineering Societies should be spread before the entire reading public, to the end that the brain workers and all thinking people are consolidated into a social force which moves steadily forward by the light of scientific facts and the newly disclosed laws of mentality, rather than by their present guidance of sensational news and a press inspired by political and selfish class bias. Like the Pilgrim at Plymouth Rock, all our people should work and live "for ye generale good of ye colonie."

If the engineers direct their study of mentality and social science along this program, they can perform their duty to society and truly succeed in "directing aright the tendencies of the day." Let us illustrate the possibilities of such social studies, by citing some of the most important problems, which we can solve by the application of scientific research and experimentation, the medium by which we evolved our engineering industries.

1. The changed condition of the land, of agriculture and our homes, is perhaps the most fundamental subject which requires study and correction. Our nation has shifted from an agricultural, home-farm-owning population to a city-dwelling, home-renting, industrial population. Our engineering industries have caused this shift. The land and agricultural problem of the world is truly vital. In Mexico, the incessant revolution is primarily a land question, a fight of the people to get the land, from which to make their living. Japan seeks more land and increased natural resources to relieve her population pressure. We in the United States have a serious land problem. It is a recently recognized law that as a nation declines in agriculture and the people give up ownership of their farms and move to the cities to gain their livelihood by commerce or industry, they become effeminate. Men and women copy each other's clothes. The people lose their individuality, their personal initiative, their military spirit and their home instinct. They become a metropolitan conglomerate. The birthrate declines, because husband and wife are absorbed in material selfishness, rather than in home, parenthood and the love of children. They lose their finer intellectuality. The drama, art, music and literature decline, the religion dies. When religion dies in a nation, as it is doing in America today, that nation dies. Babylon, Greece and Rome dominated the world, so long as their people lived on their own land and centered their lives in their homes, their families and their religion. They perished at the hands of mediocre barbarians, skilfully and aggressively led, who overwhelmed and conquered these seemingly prosperous people, when they became enervated by materialistic city life and the decay of their religion.

One of the most wicked and race-destroying features in this shift of ours from the land and the open country to the congested city, is the oppressive condition, whereby families with children, even with one little baby, are unable to find houses or apartments which they can rent as homes. This glaring sacrifice of the continuance of the race to the material interests of property should convince us of the need of organized scientific activity by the brain workers, in their own racial defense, that they may have their homes and rear their children. We are so saturated with the grossly selfish spirit, that "it doesn't matter what happens, so long as it doesn't happen to us," that we folks of the engineering industries are undertaking no effective action to assure the next generation an opportunity to enter the world. Unless there be abundant and attractive homes, with happiness and contentment for the next generation, there will be no brain workers to direct the industries we have created, and our plants will fall in ruins, like New York or New England abandoned farm homesteads. Property without people is worthless. Property without people is a wilderness, a desert.

2. Formerly the child learned life by living. The household arts which used to supply home technical training have been almost completely superseded by factory manufactured food and clothing. Water, light, and fuel for cooking are delivered to our homes through pipes or over wires, displacing the old oaken bucket and the chain pump, the bucksaw and the woodpile, and the kerosene lamp. The waterwheel at the brook, the wind-wheel on the woodshed, the figure 4 trap and the muzzle loading shotgun have been supplanted by Mary Pickford and Charlie Chaplin, witnessed seated, in a dark room. Healthful play at home is rarely possible, for there is neither room nor play space. Play is transferred to city parks, where unmarried women of advanced years are hired to teach children to play.

The schools of former days and the long summer vacation were designed for New England and New York village and farm life. The education of that time was adequate, and the training in practical life

which children received from their daily work at home produced self-reliant, resourceful Yankees. The industrial changes of the past thirty-five years have robbed children of active experience in life and have given them passive, commercialized amusement instead.

Our engineers' study should devise means for bringing the children back into touch with agriculture, industry and civics. This can easily be accomplished by conducting the children on study trips to all these activities of daily life and using them as the basis of broad, liberal education. If the instruction include the relation of the entire world to local daily life, if the training be directed literally to the education, the drawing out, of the child's mind, his memory of school, when he goes into the world, will be as vivid and exhilarating as that of a world-series baseball game. With such training, he will go through life reading, thinking, studying, growing; and every day becoming a better citizen and a better American.

3. The third study to which we would call attention is that of retarded marriage. The conditions of our industrial life delay and prevent marriage. It is practically an economic impossibility for women in industry to marry, unless they continue in industry and combine their income with that of the husband, in support of the children and the home, as our mothers did, at home. This disastrous condition manifests itself most destructively upon the best of our people, the old, sturdy American stock, who in three generations have dropped from eight or ten children to two or three children, and to one or no children in the present generation. We are sacrificing womanhood and motherhood to industry, at such a pace that in two generations, there will not be enough Yankee stock to carry on the engineering industries we have created. Notwithstanding this fact, we are gripped by the agricultural tradition that the obvious end and purpose of woman's life is marriage and motherhood, and we fool ourselves into the absurdity that our young women are only temporarily in industry, and that they will marry, after a few years in office or factory. Meanwhile the foundation upon which our industries exist, superior manhood and womanhood, dies for the want of planting. We are swiftly making our race extinct, as we did the American pigeon and the bison.

It is upon such subjects as these that we engineers must educate the brain workers, and with them build profound, scientifically correct public opinion, which shall result in cooperation between our industries and the universities and technical schools in practical organizations, to carry on social experimentation to correct the great evils, which begin to overwhelm us. Industrial plants are as worthless as a mountain of gold on Robinson Crusoe's island, unless there be intellectual people to use the products of industry. Through our lack of foresight, we are steadily destroying our race and rendering our property as useless as an iron mine in the mountain of the moon. Shall we continue to do so?

The question is, are we to be the leaders or the victims of progress?

THE EFFICIENCY OF INSULATION USED IN COLD STORAGE WORK

During the last few years there has been a great demand for information concerning the relative values of various materials that are used for insulation and this has led to extensive experimental investigations in different laboratories. While a great many factors, such as resistance to moisture, inflammability, strength, durability, etc., must be considered in choosing an insulating material, the material must of necessity be a good insulator and the measurement of its thermal conductivity is, therefore, the matter of most importance. The Bureau has developed and used for several years a very satisfactory apparatus for measuring thermal conductivity. The results obtained have been assembled and a standardized form of the apparatus suitable for general use has been designed. The American Society of Refrigerating Engineers has taken an active interest in this work, so that a standard apparatus may be available, the use of which will eliminate disputes due to differences resulting from the employment of unsuitable testing methods.

It may be said that the technical difficulties which led to such discrepancies have been largely overcome but a considerable amount of educational work is still necessary among the manufacturers and users of insulating materials in order to eliminate misunderstandings. The results of the Bureau's work will be published in a forthcoming number of the JOURNAL of the American Society of Refrigerating Engineers and will also be issued as a Bureau of Standards Scientific paper.

A report from Geological Survey states that the latest figures on the world's oil supply given out by Survey show that foreign countries are using only half as much petroleum as United States, but have seven times as much oil in the ground. These countries are now using about 200,000,000 barrels of oil yearly, but they have resources large enough to last over 250 years at this rate of consumption. In striking contrast are production figures for the United States which at the present rate of more than 400,000,000 barrels a year has only an 18 years' supply.

Flux Distribution in the Core of a Turbo Alternator

BY CARL J. FECHHEIMER
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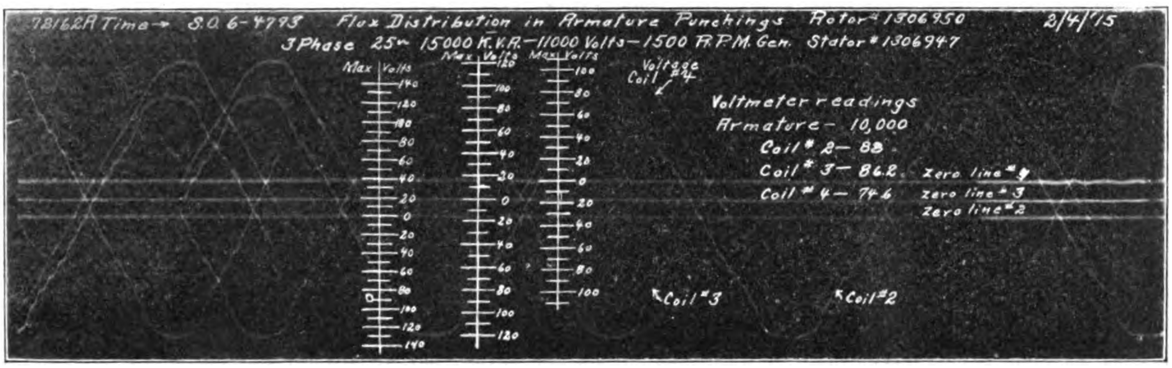
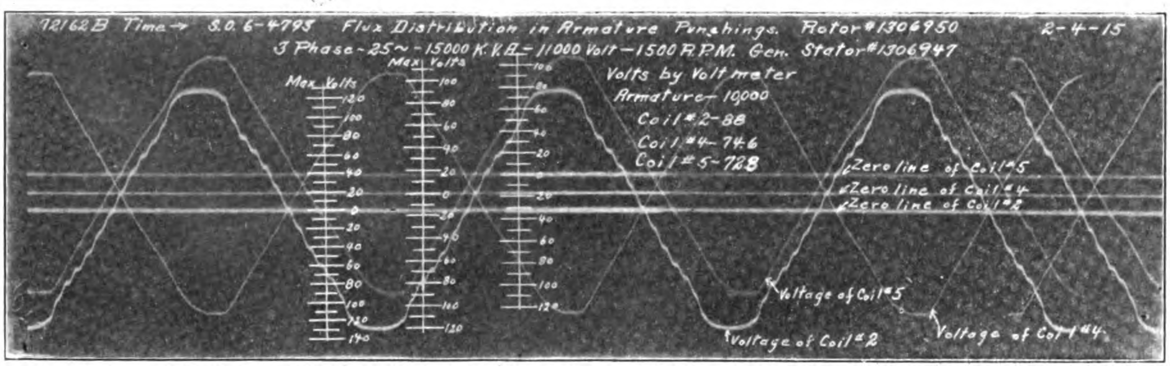
ENGINEERS have long known that the density of the flux in the cores of electrical machinery changes with the depth, but there has been considerable divergence of opinion in regard to the magnitude of such variations.

In a two-pole revolving field turbo alternator, a greater variation in density would be expected than in any other type of machine. A mathematical analysis is extremely difficult, and therefore an analysis was obtained experimentally.

The alternator on which the test was made is axially ventilated; thus, there are axial holes at different radii in the stator core. Single insulated conductors were inserted in one of each of the various holes. A voltmeter and an oscillograph were connected to the terminals of each of these conductors in turn, and by means of this arrangement the voltages, as well as the wave forms of the voltage, at various depths of core, were determined. The normal voltage of the generator is 11,000, but oscillograms were taken with the terminal voltages of 8500, 10,000 and 12,500, all at no load. The oscillograms are shown as Nos. 72162–A to 72162–L inclusive. The voltmeter readings are also recorded. A picture of the stator core is shown from Fig. 4. The coil numbers recorded on the oscillograms refer to conductors placed in axial holes shown in Fig. 4; number 1 refers to the hole in the tooth, number 2, to the first hole just back of the tooth, etc.

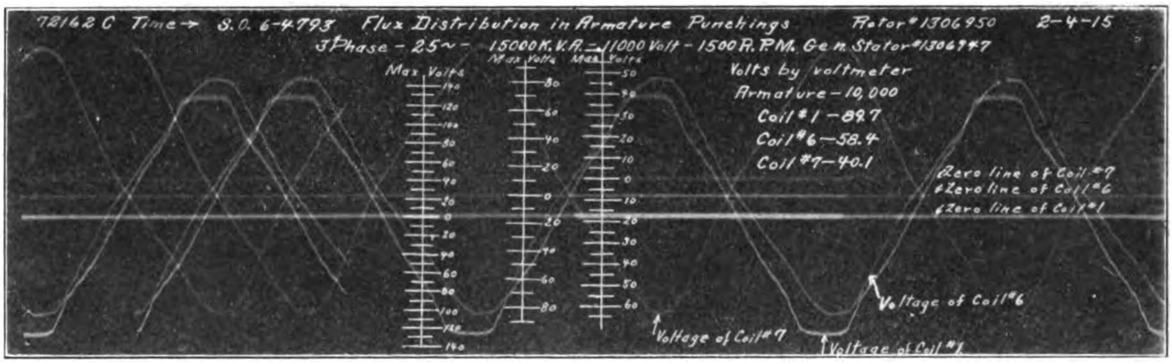


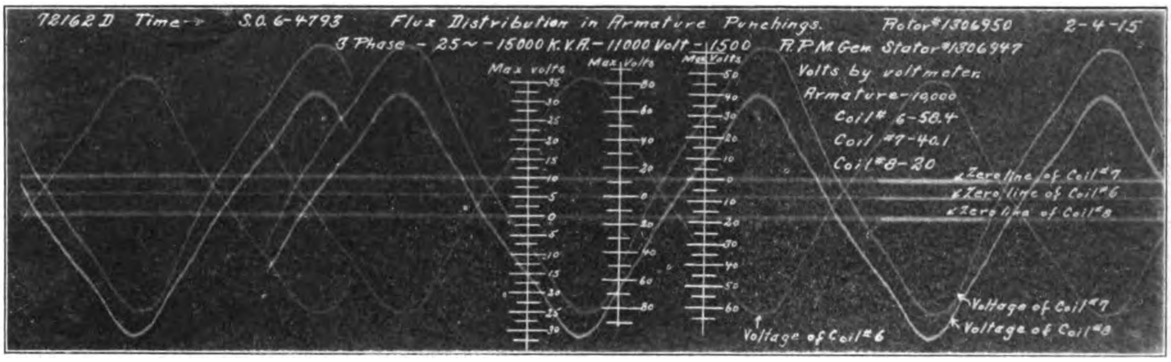


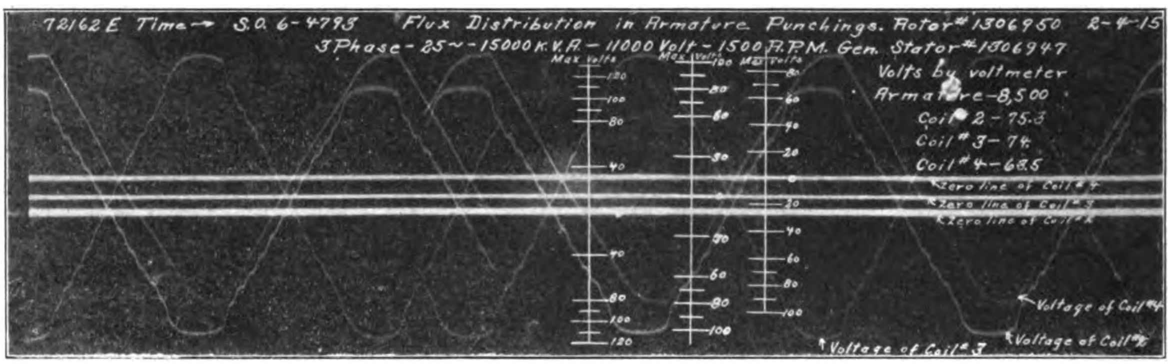
In order to determine the space distribution of flux in the core, the oscillograms at 8500 and 12,500 volts were integrated, and the results are plotted in Figs. 1 and 2. It was found that the fluxes determined from oscillograms were in agreement with those determined from voltmeter readings, allowing for slight inaccuracies in calibration in the case of the oscillograms, and for form factors as determined from oscillograms and applied to voltmeter readings.[1]

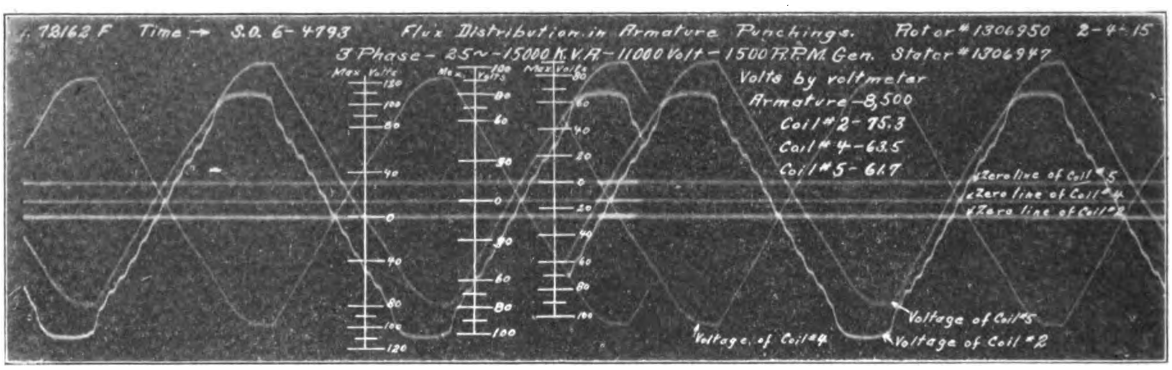
In reviewing the various oscillograms, it is of interest to note that their shapes are not the same, and the maximum points of some of the voltage waves do not come midway between their respective zero points. Thus, whereas the shapes of the waves taken on coil No. 2 at all three voltages show that there are substantially symmetrical about ninety degree lines measured from the zero points, and that their shapes are substantially the same as those of flux density distribution in the air gap, the waves taken on coils 7 and 8 are not symmetrical about ninety degree lines, nor are the voltages of these waves at maximum values at ninety degrees. On the other hand these waves all pass through zero at substantially the same instant of time. (See *e.g.* oscillograms Nos. 72162 C, 72162 G and 72162 K coils Nos. 1 and 7). Thus, the fluxes

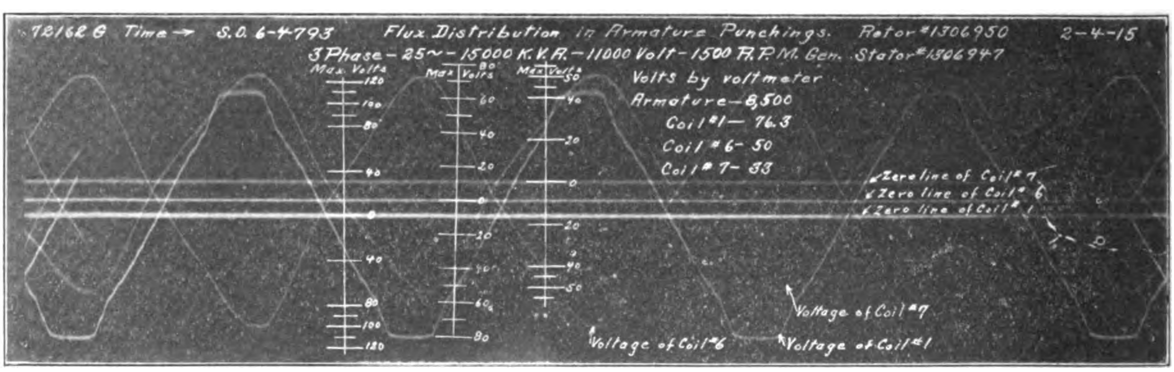
1. The method of integration adopted was the trapezoidal method, a description of which may be found in article by Bedell and Bown in *Electric Journal* for Jan. 1915.

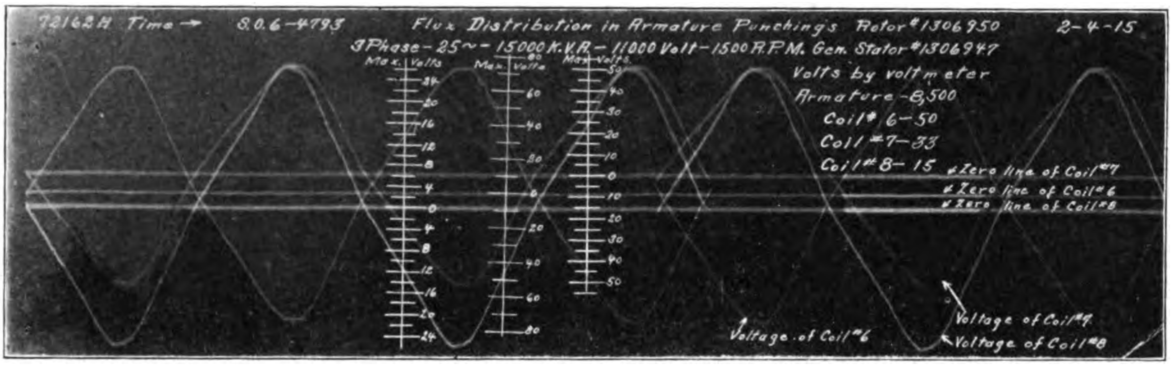

72162 C Time→ S.O. 6-4793 Flux Distribution in Armature Punchings Rotor #1306950 2-4-15
3 Phase - 25~ - 15000 K.V.A. - 11000 Volt - 1500 R.P.M. Gen. Stator #1306947
Max Volts
Volts by voltmeter
Armature - 10,000
Coil #1 - 89.7
Coil #6 - 58.4
Coil #7 - 40.1
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #1
Voltage of Coil #6
Voltage of Coil #7
Voltage of Coil #1

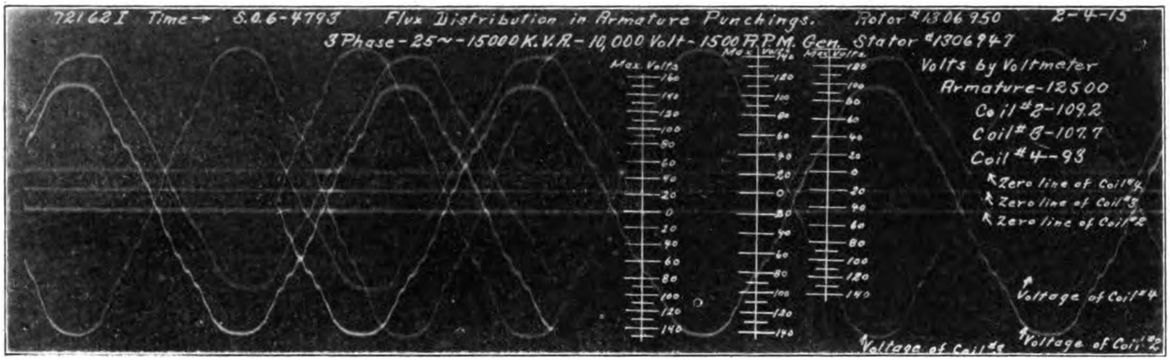

72162 D Time→ S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase - 25~ - 15000 K.V.A. - 11000 Volt - 1500 R.P.M. Gen. Stator #1306947
Max volts
Volts by voltmeter
Armature - 10,000
Coil # 6 - 58.4
Coil #7 - 40.1
Coil #8 - 20
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #8
Voltage of Coil #6
Voltage of Coil #7
Voltage of Coil #8

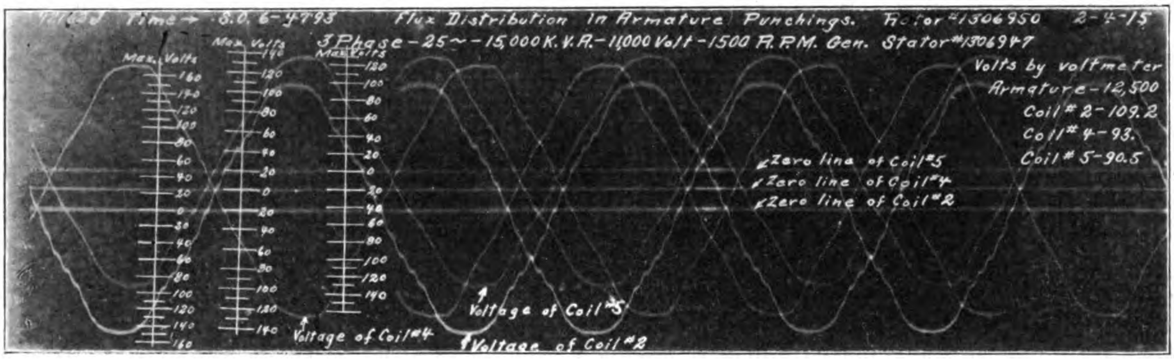

72162 E Time→ S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase - 25~ - 15000 K.V.A. - 11000 Volt - 1500 R.P.M. Gen. Stator #1306947
Max Volts
Volts by voltmeter
Armature - 8,500
Coil # 2 - 75.3
Coil #3 - 74
Coil #4 - 63.5
Zero line of Coil #4
Zero line of Coil #3
Zero line of Coil #2
Voltage of Coil #4
Voltage of Coil #3
Voltage of Coil #2

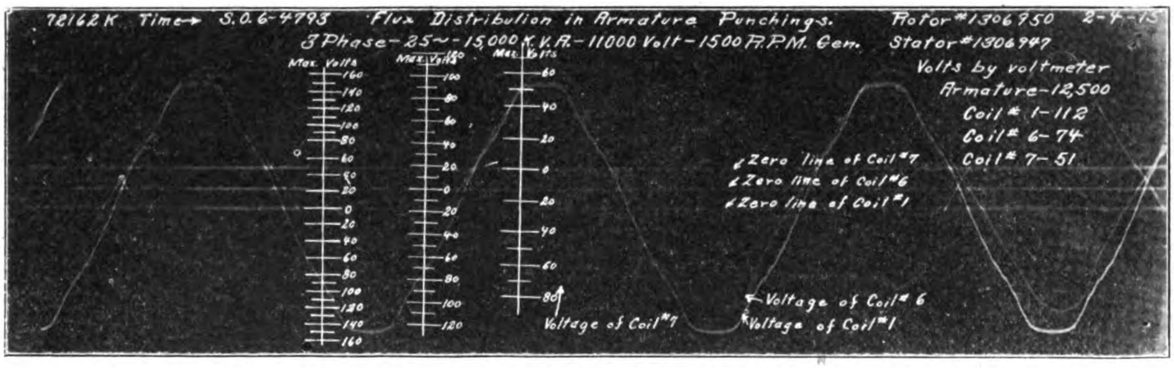

72162 F Time→ S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase - 25~ - 15000 K.V.A. - 11000 Volt - 1500 R.P.M. Gen. Stator #1306947
Max Volts
Volts by voltmeter
Armature - 8,500
Coil #2 - 75.3
Coil #4 - 63.5
Coil #5 - 61.7
Zero line of Coil #5
Zero line of Coil #4
Zero line of Coil #2
Voltage of Coil #5
Voltage of Coil #4
Voltage of Coil #2

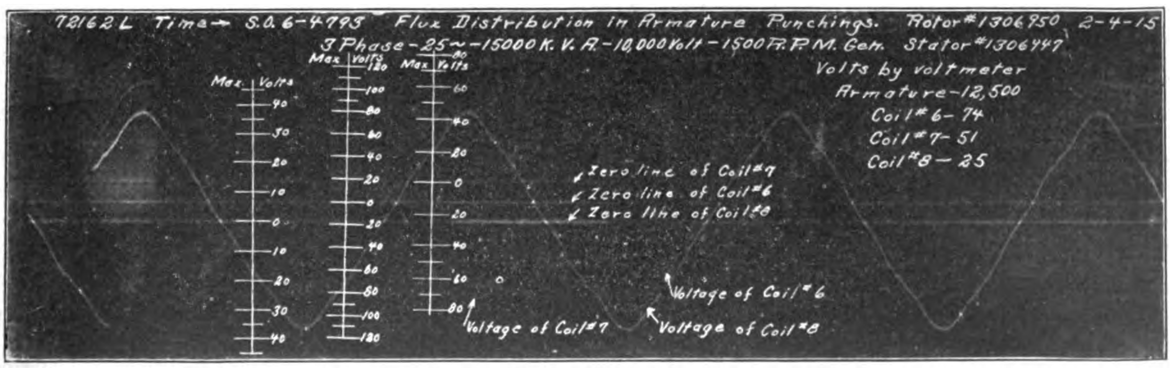

72162 G Time→ S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase - 25~ - 15000 K.V.A. - 11000 Volt - 1500 R.P.M. Gen. Stator #1306947
Max Volts
Volts by voltmeter
Armature - 8,500
Coil #1 - 76.3
Coil #6 - 50
Coil #7 - 33
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #1
Voltage of Coil #7
Voltage of Coil #6
Voltage of Coil #1


72162H Time → S.O. 6-4793 Flux Distribution in Armature Punchings Rotor #1306950 2-4-15
3 Phase-25~-15000 K.V.A.-11000 Volt-1500 R.P.M. Gen. Stator #1306947
Volts by voltmeter
Armature-8,500
Coil # 6-50
Coil #7-33
Coil # 8-15
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #8
Voltage of Coil #6
Voltage of Coil #7
Voltage of Coil #8


72162 I Time → S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase-25~-15000 K.V.A.-10,000 Volt-1500 R.P.M. Gen. Stator #1306947
Volts by Voltmeter
Armature-12500
Coil #2-109.2
Coil #3-107.7
Coil #4-93
Zero line of Coil #4
Zero line of Coil #3
Zero line of Coil #2
Voltage of Coil #4
Voltage of Coil #3
Voltage of Coil #2


72162J Time → S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase-25~-15,000 K.V.A.-11,000 Volt-1500 R.P.M. Gen. Stator #1306947
Volts by voltmeter
Armature-12,500
Coil # 2-109.2
Coil # 4-93.
Coil # 5-90.5
Zero line of Coil #5
Zero line of Coil #4
Zero line of Coil #2
Voltage of Coil #5
Voltage of Coil #4
Voltage of Coil #2


72162K Time → S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase-25~-15,000 K.V.A.-11000 Volt-1500 R.P.M. Gen. Stator #1306947
Volts by voltmeter
Armature-12,500
Coil # 1-112
Coil # 6-74
Coil # 7-51
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #1
Voltage of Coil # 6
Voltage of Coil #7
Voltage of Coil #1


72162L Time → S.O. 6-4793 Flux Distribution in Armature Punchings. Rotor #1306950 2-4-15
3 Phase-25~-15000 K.V.A.-10,000 Volt-1500 R.P.M. Gen. Stator #1306947
Volts by voltmeter
Armature-12,500
Coil #6-74
Coil #7-51
Coil #8-25
Zero line of Coil #7
Zero line of Coil #6
Zero line of Coil #8
Voltage of Coil #6
Voltage of Coil #7
Voltage of Coil #8

must reach their maximum values along the same radial lines in the machine at all depths of core (for all three voltages), but are not zero along the same radial lines for all depths of the stator core. Furthermore, the distortion is less marked at 12,500 volts than 8500 volts for those coils toward the back of the core. Compare coil No. 8 on 72162-H for 8500 volts with No. 8 on 72162-K for 12,500 volts). Figs. 1 and 2 will give a clear picture of flux distribution radially and circumferentially. Note the points where the fluxes are maximum and where the fluxes are zero, and also compare the slight dissymmetry of No. 7 on Fig. 1 with the symmetry of No. 7 on Fig. 2. This distortion and time lag of flux are without doubt due to hysteresis and eddy currents; the former produces a direct time lag of flux and the latter sets up counter magnetomotive forces, thus delaying the time that the flux passes through zero. The less degree of distortion at the higher voltage is no doubt due to the effect of saturation with the high core densities then obtaining.

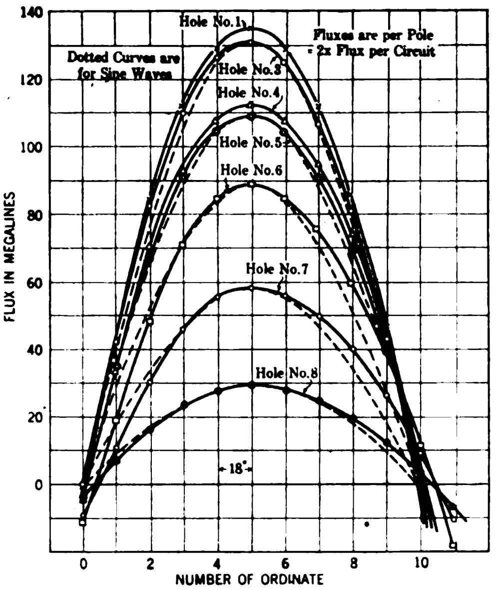


FIG. 1—FLUX BACK OF VARIOUS HOLES—8,500 VOLTS

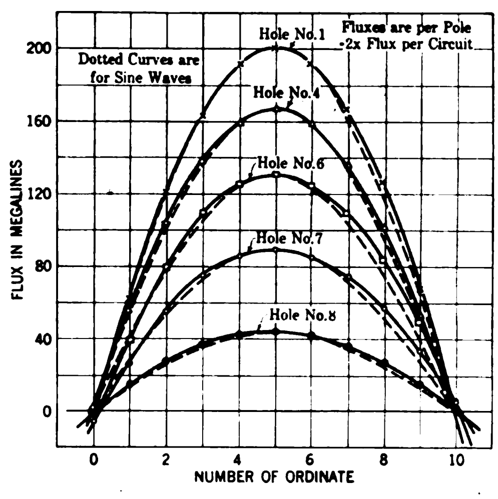


FIG 2—FLUX BACK OF VARIOUS HOLES AT 12,500 VOLTS

From the data obtained, it has been possible to draw the approximate curves in Fig. 3, these being based upon the maximum values of fluxes from curves in Figs. 1 and 2 and sections between adjacent sides of consecutive holes. If we call R_2 the outer radius, r any radius, B_0 the density at radius R_2, (K being a constant) then these curves may be quite closely approximated by equation:

$$B = B_0 + K (R_2 - r)^{3/2}$$

If R_1 is the inner radius, the average density is:

$$B_{av} = \frac{1}{(R_2 - R_1)} \int_{R_1}^{R_2} [B_0 + K (R_2 - r)^{3/2}] d r$$

$$= B_0 + \frac{2}{5} K (R_2 - R_1)^{3/2}$$

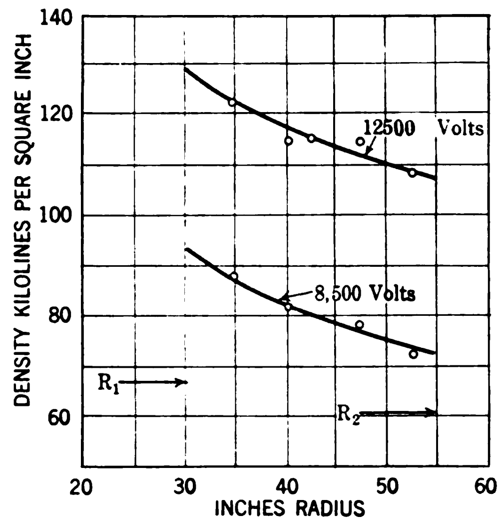


FIG. 3—FLUX DENSITY IN CORE

Thus we find the average densities for the two curves, which agree within about one per cent with the average densities figured from the total fluxes and total section; that is, within error of plotting, etc. Thus we find the following for the two curves in Fig. 3:

Volts	8500	12,500
$\frac{\text{Dens. at } R}{\text{av. dens.}}$	0.900	0.93
$\frac{\text{Dens. at } R_1}{\text{Av. dens.}}$	1.15	1.110
$\frac{\text{Dens. at } R_1}{\text{Dens. at } R_2}$	1.270	1.195

Fig. 3, we believe, to be valuable in that it shows the comparatively small change in density with depth, even with negligible saturation as at 8500 volts. Much of the flux reaches the back of the core even though

the length of its path is considerably longer than at the inner radius.

On Figs. 1 and 2 a number of sine waves have been plotted in dotted lines to indicate the degree of departure of the flux waves in space from the ideal sine distribution. We have previously referred to the dis-

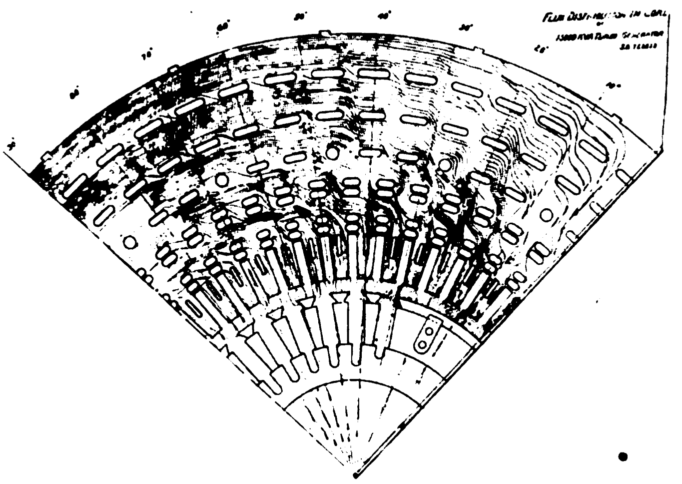


Fig. 4

tortion, and it will be seen that if in Fig. 1 the waves for holes 6, 7, and 8 be turned slightly about their point of maximum density, their departure from sine space distribution will not be very great. The other waves in Fig. 1 and 2 agree sufficiently with the sign curves to enable sine wave distribution to be assumed

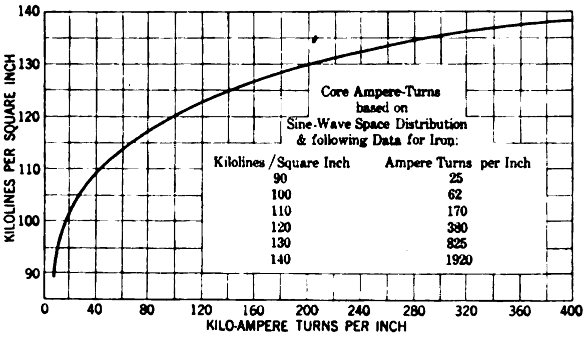


Fig. 5

for calculations. Especially at the higher voltages will this be true (Fig. 2), and we therefore assumed sine wave space distribution in calculating densities which enabled the drawing of flux distribution, shown in Fig. 4. Thus Fig. 4 does not show one distortion which is especially pronounced when the flux passes through zero at the lower voltages but is nearly negligible at 12,500 volts for which Fig. 4 is drawn. Even with sine wave space distribution Fig. 4 is only approximately correct, and its purpose is solely to give a slightly clearer picture of the distribution in the core.

We may employ the assumed sine wave distributon for estimating the ampere turns required to drive the flux through the stator core, which may be of assistance in predicting saturation curves. We take the ampere turns needed for the mean length of path for the mean density to be the same for any depth. The curve which we have calculated is shown in Fig. 5. To illustrate the method, calculations at average density of 130,000 lines per square inch are given below:

				B	A. I. inch
First........	5 deg.	130 cos 2 ½ deg.	=	130	825
Second......	5 deg.	130 cos 7 ½ deg.	=	129	755
Third.......	5 deg.	130 cos 12 ½ deg.	=	126.9	640
Fourth......	5 deg.	130 cos 17 ½ deg.	=	124	500
Fifth........	5 deg.	130 cos 22 ½ deg.	=	120.2	380
Sixth.......	5 deg.	130 cos 27 ½ deg.	=	115.3	265
Seventh.....	5 deg.	130 cos 32 ½ deg.	=	109.7	160
Eighth......	5 deg.	130 cos 37 ½ deg.	=	103.1	85
Ninth.......	5 deg.	130 cos 42 ½ deg.	=	95.8	42
Tenth.......	5 deg.	130 cos 47 ½ deg.	=	87.8	22
Eleventh....	5 deg.	130 cos 52 ½ deg.	=	79.1	15
				Total amp. turns =	3689

The ampere turns beyond the eleventh 5 deg. are neglected, but we may consider the 3689 ampere turns as having covered 90 electrical degrees. As we have considered five electrical degrees to correspond to one inch of length, 90 degrees correspond to 90/5 = 18 inches. The ampere turns per inch will be 3689/18 = 205. In using Fig. 5, figure the average core density in ordinary way, and then use as length

$$\frac{\text{(External diameter} = \text{depth of core).}}{\text{Number of poles}}$$

Result will be in ampere turns per pair of poles.

It is well-known that, per pound of material, the core losses, in radially slotted rotor type of turbo alternator, are usually materially less than in salient pole alternators, although higher than in transformers. Undoubtedly, the lowered rate of change of flux density due to the approximate sine wave space distribution of flux as compared with the more abrupt rate of change in the salient pole machine, is to a large extent responsible for this reduction. Another cause may be attributed to the lower percentage of iron loss in the stator teeth of the turbo owing to the great depth of cores in that type compared with the general proportions to be found in salient pole alternators.

Portable Oscillograph

BY J. W. LEGG

Westinghouse Electric & Mfg. Co.

Introduction

THE use of the oscillograph for recording the instantaneous values of electrical phenomena has steadily increased in both scholastic and commercial institutions. Formerly it was seldom necessary to use the oscillograph in the field. However, due to the increasing complexity in transmission circuits and in railway electrification problem, it has become more and more desirable to have a special, portable, commercial oscillograph which, besides having the properties of the best laboratory oscillograph shall also be extremely compact and light in weight.

This article describes such an oscillograph which, furthermore, is permanently assembled in two units, which have been taken by the engineer into a Pullman to the place of test, and set up, ready for use in half an hour's time. There are many novel features in this oscillograph which make it independent of a direct-current supply, and which makes it adjustments more permanent, its operation more simple, and its results more reliable than heretofore possible with other forms of oscillographs.

The Oscillograph and its Galvanometer

An oscillograph consists essentially of an optical system for throwing a beam of light onto the vibrating mirror of the galvanometer which mirror in turn reflects this beam of light onto a photographic film, passing at right angles to the vibrating beam, some distance from the galvanometer. This makes a *current-time* record, on the film; in which *distance* along the film is proportional to *time*, and *deflection* (of the beam of light) is proportional to the *instantaneous* value of *current* passing through the galvanometer vibrator.

Several standard makes of the moving coil oscillograph galvanometer were considered when the writer first planned a more portable commercial oscillograph. The permanent magnet type was light in weight but did not have a short enough natural period of oscillation to act properly on very fast transients or to respond to the high harmonics in some alternating current waves. The best standard electromagnet types of oscillograph galvanometer were superior in characteristics of natural period and sensitivity but were bulky and required a supply of direct current (usually 110 volts). Both of these drawbacks were serious for a portable commercial oscillograph, and hence an entirely new galvanometer and accompanying apparatus were designed to fulfill the more exacting requirements.

Surmounting Former Difficulties

This oscillograph was designed to be independent of direct-current supply, for it is often desirable to make oscillograph records in a power-house, substation, factory, etc., where there is either no direct-current supply or where the supply is unreliable, due to sudden voltage changes. Former oscillograph apparatus which used d-c. for the galvanometer fields, arc lamp, electrically operated shutter, etc., required a two-kw. motor-generator set, or a large storage battery (which had to be kept charged) when no suitable d-c. supply was already available. Such was usually larger and much heavier than all of the other oscillograph apparatus combined.

As alternating current is in much more general use, for lighting and for power, the light source and the film motor were designed to operate on a-c. An incandescent lamp was used (with special means to give the filament great intrinsic brilliancy), the photographic shutter was designed to operate mechanically, and the galvanometer field circuit to operate on ten watts, supplied by a small storage battery, all being enclosed in the oscillograph case. This case also contains the low and high resistances, for each of the three galvanometer elements, in order that they may be used for any potential up to several thousand volts.

The lamp and the film motor are operated from a small transformer which may be plugged into any ordinary lamp socket or power supply of approximately *110 or 220 volts at any frequency from 20 to 70 cycles*. Thus this portable apparatus requires, momentarily, less than 300 watts, a-c., instead of 2000 watts, d-c. (as was formerly required).

If a test is to be made where there is no alternating current supply, the gas filled incandescent lamp may be readily removed and an external d-c. arc lamp substituted. Also a d-c. motor can be used in place of the induction motor, for driving the photographic film. In practise it has been found that alternating current is almost always available, while proper direct current is seldom available outside of the laboratory.

A general view of the portable oscillograph is shown in Fig. 1. The main oscillograph case is shown to the left. This is 14 inches high, 13 inches wide, and 25 inches long over all. It contains the lamp house. shown at extreme left, the galvanometer, in the rear upper part of the case, the optical box, to which the photographic drum is attached, the ammeter and control switches, the element resistances with their control panel and the storage battery.

To the right is shown the motor board, on which are mounted: the induction motor with helical gears. for driving the photographic drum at desired speed. the transformer, and the control panel, with switches, fuses and lamp rheostat.

These two units together weigh but 135 pounds including side covers and carrying arrangement. They

take the place of former apparatus which weighed (ready for shipment) *from one-half to two tons* (depending whether or not suitable 110-volt direct current was available at the place of test).

The *galvanometer* is shown in Fig. 2. This instrument is 7 inches square, at the base, and 4¼ inches high over all. There are three separate elements, each insulated for over 10,000 volts from its neighbor. The most novel feature is the electromagnetic series field circuit. There is but a *single* exciting coil which forces the magnetic flux in a *series path* through the three elements. There are three effective gaps in the iron circuit, one for each element, and four *insulating gaps*. The effective gaps are small in cross-section so as to concentrate the magnetic flux about each vibrating element. The insulating gaps are of micarta and are large in cross-section so as to have the least possible reluctance and still present sufficient insulation between the elements. This design is so efficient that it requires but 10 watts, applied to the field coil to nearly saturate the element pole tips, thus giving as strong a magnetic field as is practical.

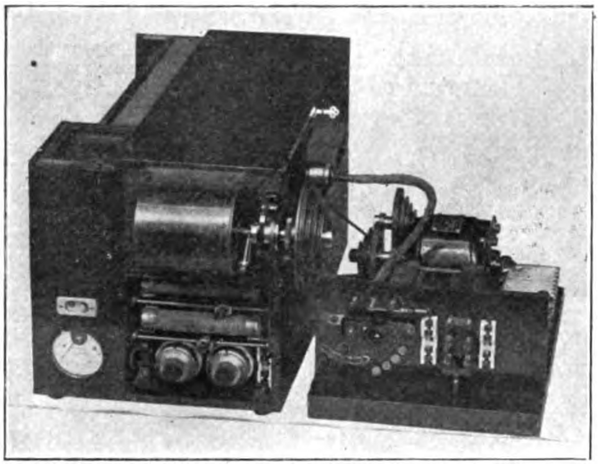


Fig. 1—Portable Oscillograph in Two Units

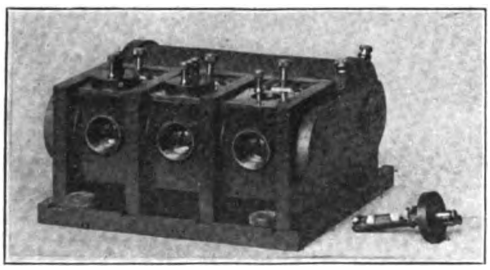


Fig. 2—Three-Element Galvanometer Series Magnetic Circuit

One *vibrator element* is shown to one side, the other two elements are in place in their wells. These wells contain the damping fluid which prevents over-travel of the vibrating mirrors. They are closed by the element tops so as to be both dust and oil tight. This feature is quite important for a portable oscillograph. The very fine ribbon of metal, which forms the moving coil of the galvanometer, is entirely immersed in oil. A low resistance of the same material, is mounted in air so that it will clear the circuit, when an excessive current passes, and thus save the element.

As is the case with most *moving coil oscillograph galvanometers*, the coil actually consists of a single turn of very fine conductor, supported by two ivory bridges so that the effective part of the coil is essentially two parallel wires with the current passing down one wire and up the other. The motoring action of the conductors, carrying a current at right angles to the lines of force of the magnetic field, tends to force one wire forward and the other backward, in proportion to the current passing through them. These parallel conductors are kept taut by a tension spring which transmits its force to the loop through a lever and a tiny ivory pulley. The lever is *balanced* so that any shock will not tend to break the fine conductor. A very small mirror bridges the parallel conductors at the center of the magnetic gap. This reflects the beam of light to the photographic film. With this optical advantage the deflection is approximately one inch to 0.12 ampere. Any element may be used across a shunt, as a millivoltmeter, to record instantaneous current, or, with a series resistance, to record instantaneous values of voltage.

Fig. 3—Panel Side of Oscillograph Case

Fig. 3 shows the front and the element resistance *panel side of the ocillograph.* There are three similar sets of switches and binding posts, one set for each element. Each set consists of two dial resistances, one with a range from 0 to 100 ohms and the other from 100 to 10,000 ohms. The double-pole, double-throw knife switch places the element, and its fine fuse, in series with either the high-resistance or the low-resistance dial. There are four binding posts per element. The two closer together are in the low resistance circuit, for use with e.m.fs. below 10 volts, or for connection across a current shunt. The other two posts have a greater spacing to indicate that they are to be used for higher voltages, with the higher resistance. With this connection the element can be used to record the instantaneous values of e.m.f. up to about *4000 volts*, d-c., or about 1500 volts, a-c. In every case the resistance is nearest the left hand

terminal so that when high voltage is used the right hand terminal can be kept in the side of the line nearest the ground, thus keeping the element on the ground side. If more than 10,000 ohms is desired, in one element circuit, one of the other high resistances can be connected into circuit.

This whole panel, with all the resistance units, can be removed from the oscillograph for inspection or or repair. The resistances are wound on thin micarta cards, so as to be as non-inductive as possible. They are located behind the panel, underneath the galvanometer compartment.

The adjusting screw for the incandescent lamp is shown below the smoked glass window and above the battery charging terminals.

A fine wire screen between the element resistance panel and the galvanometer partition, allows ventilation of the element resistances.

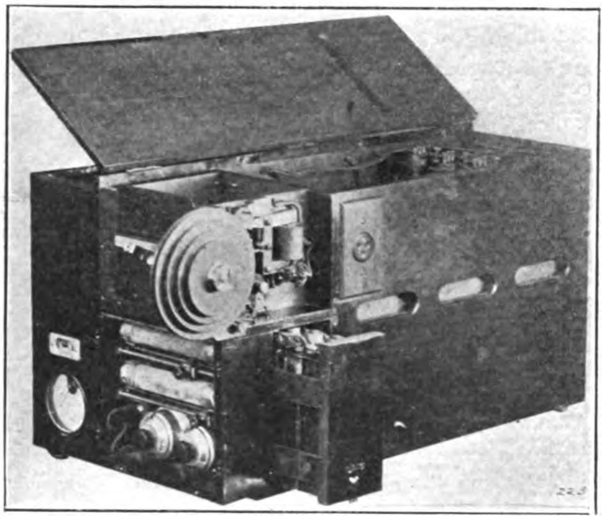


FIG. 4—BATTERY COMPARTMENT SIDE OF OSCILLOGRAPH

One of the *snap switches,* in front, connects the ammeter to indicate either the galvanometer field current or the battery charging current. The normal field current is 2¼ amperes. The conveniently located switch, above the ammeter, is in the field circuit and is used to conserve the battery current when no charging current is at hand. The variable resistances are in the battery and galvanometer field circuits.

Fig. 4 shows the *battery compartment side of the oscillograph.* The common cover to the galvanometer compartment and optical box is shown in its raised position. The top of the galvanometer can be seen at the rear. Below this is the element resistance compartment with 30,000 ohms of non-inductive resistances. The three longitudinal ventilating slots can be seen at the side. There are nine similar slots in the base, to allow cool air to enter below the resistances.

The *storage battery* is shown half withdrawn from its compartment. Above is shown the rectangular plate with the three-point plug receptacle, used in connecting the incandescent lamp and trip magnet mechanism to the low-voltage side of the transformer. The trip magnet is shown on the side of the optical box, in a recess near the film pulley.

Fig. 5 is a detailed view of the trip magnet, remote-control switch, photographic shutter release, lamp-extinguishing switch etc. These are all novel features and all add greatly to the efficiency and simplicity of operation of the oscillograph.

As mentioned before, *the shutter is mechanically operated* and is of the semi focal-plane type. This is

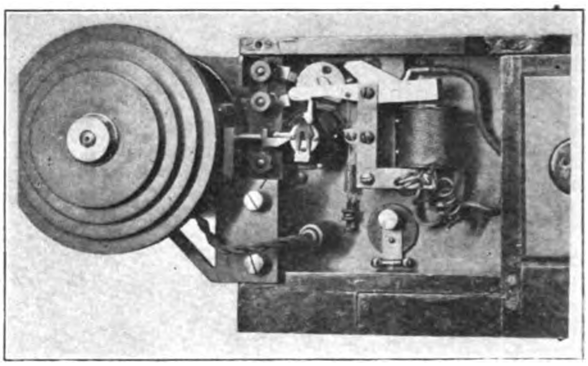


FIG. 5—SHUTTER TRIP AND REMOTE CONTROL MECHANISMS

so arranged as to permit the reflected beams from the tiny vibrating mirrors to strike the film for just one complete revolution. Also the start of the exposure always comes very near the beginning of the rectangular film. *With this arrangement no important transient could ever occur just at the overlapping of the film.*

The *shutter* is essentially a hollow cylinder with a longitudinal slot on each side. When these slots line up, horizontally, the shutter is open. The cylindrical condensing lens lies just between the shutter and the film holder.

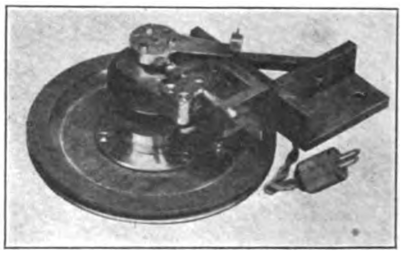


FIG. 6—DRIVING HEAD

The *shutter operating device* is in two main parts. The radial fingers and hub, on the shutter shaft, receive a torsional force from the spiral spring. The release arm is actuated, through a connecting rod, by a crank pin on the film pully shaft. When all is ready for the phenomena to be recorded on the photographic film, the trip magnet releases the longer of the two radial fingers; this allows the shorter finger to rest on the release arm. When the arm almost reaches its extreme travel, away from the shutter, the short arm drops, due to the torsional force exerted by the

spiral spring, the longer finger is stopped by the arm, thus holding the shutter open. As the arm returns it forces the longer finger into the hub, and as it moves outward again a flat spring holds this finger in, so that it is now just the same length as the first finger. When the arm reaches its outward position again the second finger drops and the shutter closes, after allowing just one revolution exposure on the revolving film.

The instant the *trip magnet* is excited it releases the remote control switch, but the shutter does not open until the overlapped end of the film is presented towards the galvanometer. A contact on the film pulley shaft,

Fig. 7—Optical Box

may be set so as to trip the magnet at any interval of time, ahead of the exposure, equal to the time lag of the remote controlled apparatus (circuit breaker, switch, relay, fuses, etc.) being studied. Thus, if the operator desires, he can cause the transient phenomena to occur within 0.01 sec. after the beginning of the exposure. This is of *great value for commercial work,* where many fast transient conditions must be recorded.

Fig. 7 shows the *optical box* on its face with the under side nearest the observer. This is made of aluminum so as to be as light in weight as possible. The trip magnet, shutter fingers, observation door, etc., can be seen to the left. The condensing lens is adjustable and can be twisted to one side when an external arc lamp is to be used. There are four reflecting prisms and slots, one set for each element, and one for a stationary beam or for a timing line device. All of these are very conveniently adjusted from above, their knurled heads being in plain view when the main cover is raised. Furthermore, when using the incandescent lamp, these various items need to be adjusted but once, and then *any number of oscillograms may be taken without further adjustment,* until renewal of the lamp.

Fig. 8 shows a close up view of the *motor board.* The rheostat switch on the panel, is in the lamp circuit, which is supplied from the low-voltage secondary of the transformer. The first contact closes the lamp circuit through sufficient resistance to give normal voltage to the lamp. This *lamp* is of the low-voltage, high-current type with an extremely concentrated filament. The central part of this filament is arranged to have maximum intrinsic brilliancy, its normal brightness being increased by the light from the surrounding coil of the filament. Intrinsic brilliancy, and not total candle power, is of prime importance, for only a projected area of about 20 miles square can be used to any advantage.

The second contact position, on the *lamp control switch,* increases the voltage, applied to the lamp, by about 12 per cent, the third by 30 per cent, and the fourth by 60 per cent. The lamp would burn continuously, many hours, on 112 per cent voltage, but would have a short life at 130 per cent volts. At 160 per cent voltage, filament life would be less than one second. For this reason an automatic *lamp extinguishing switch* is used. This is located between the trip magnet core and the optical box. The closing of the shutter snaps open this special switch. The lamp cannot be lighted except when the shutter is set. A special combination stop and contact is provided, under the lamp control switch arm, so that the instant the desired abnormal voltage is applied, to the lamp, the trip magnet operates the remote-control switch, the shutter opens, the oscillograph record is made, the shutter closes, and in so doing opens the lamp extinguishing switch, thus saving the lamp. With this arrangement hundreds, and possibly thousands of films may be taken before the lamp burns out. The value of the abnormal voltage chosen depends on the speed of the film, for high-speed films require much greater intrinsic brilliancy than low-speed films.

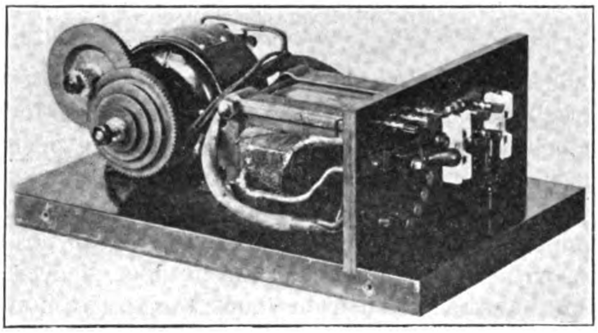


Fig. 8—Motor Board, With Transformer and Control Switches

Note that the lamp is thus at the greatest abnormal voltage for the shortest period of time, and at a moderate voltage for a longer period of time. The abnormal voltage increases the intrinsic brilliancy *many times,* thus enabling one to take oscillograms, with this incandescent lamp, which otherwise would require a direct current arc lamp consuming ten to twenty times as many watts. For some very special work, where the film speed must be greater than about 100 inches per second, it becomes necessary to use a direct-current arc. This can be applied to this oscillograph

in a few moments time, when direct current is available. If great accuracy is required in *recurrent phenomena* (such as in determining wave forms) it would be much better to *use the synchronous polar film*[1] with the incandescent lamp, than to try to get a large scale wave on the rectangular film.

The double-pole double-throw transformer switch places the two primary coils in series or in parallel; the former for 220-volt, and the latter for 110-volt supply. The single-pole switch throws the induction motor on 110 or 55 volts, for 60 or for 25-cycle supply. Actually the motor will run on any frequency from 20 to 70 cycles.

The four steps in the *pulleys*, together with the *helical gears*, give an ideal range of speed reductions. When the motor pulley is pushed in, a clutch engages with the motor shaft and gives direct drive. When this pulley is pulled out it is driven, through the back gearing, at one sixteenth motor speed. The four steps, for the round belt, are so arranged that the center distances are the same, for the four belt positions.

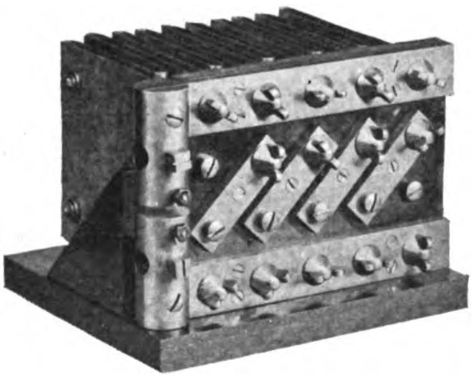


FIG. 9—VARIABLE SHUNT

Provided the induction motor supply does not vary in frequency the film speed remains the same for any one belt position, within a fraction of one per cent. This is a great advantage, for *no timing wave is needed*, on any film, after the film speed has once been determined, for that particular belt and gear position. Also, with this arrangement the number of cycles on a film, may be varied from about two to two hundred and forty. This is a greater range than is needed for any but a commercial oscillograph.

Fig. 9 shows the variable, non-inductive shunt which was designed to go with the portable commercial oscillograph. It consists of five manganin strips with special arrangement for connecting any number of them in series or in parallel. Furthermore their arrangement makes them very nearly non-inductive. When the five strips are all in series the resistance drop is great enough to give a good deflection, on the above oscillograph, with a shunt current of 10 or 20 amperes. With the strips all in parallel, approximately the same deflection would be produced by 500 amperes as was produced by 20 amperes in the series position. The shunt will carry about one thousand amperes continuously and can be used for momentary currents of 50,000 amperes.

The heavy terminals, to the left, receive the power conductors. The arrangement for connecting the strips either in series or in parallel is very convenient. Two heavy brass screws are connected to each end of each of the five strips. One from the right hand side of each strip passes through one bus bar, but is insulated therefrom; and one from the left hand side of each strip passes through the other bus bar, likewise. As the wing nuts are turned down, on these screws of any one strip, that strip is placed across the bus bars. A set of four diagonal conductors, screws and wing nuts make it possible to connect any number of the strips in series. One series-parallel arrangement is also possible. If the drop across the shunt makes too great a deflection, when the element is connected straight across it, series resistance is added in the element circuit by means of the upper dial switch shown in Fig. 3. The resistance of the strips was so chosen that 50 amperes direct current through one strip, gives a deflection of once inch, with no series resistance added to the element circuit. With five ohms, series resistance, added to the element circuit it takes 300 amperes to give one inch deflection. In general the following formula holds, approximately.

Where A = current in amperes D = deflection on film in inches.

P = number of strips in parallel S = number in series.

R = external resistance in element circuit, in ohms.

50 = amperes in one strip to give one inch deflection on film with no external resistance in element circuit.

Then $A = 50D\ (1 + R)\ P/S$ or, sensitivity = amperes per inch = $50\ (1 + R)\ P/S$.

Except for approximate work any oscillograph should be calibrated by passing a steady value of direct current through the particular shunt being used with the same resistance in series with the element as was used in the important test. If this requires a very large current (to give the proper deflection) the true calibration could be figured from the results of a calibration obtained with a much lower current passing through a much higher resistance shunt; the currents required to give the same deflection being inversely proportional to the shunt resistances. Thus, 200 amperes passing through the five strips in series would give approximately the same deflection, on the film, as 5000 amperes flowing through the five strips in parallel. When the exact ratio of resistances is known this can be figured quite accurately.

This one shunt is suitable for a *very great range* of

1. L. W. Chubb, *Electrical Journal*, May 1914.

work, and yet can be carried in a space 10 by 10 by 8 in. Naturally, however, it cannot be extremely light in weight and still be suitable for even a momentary current of 50,000 amperes.

For heavy alternating currents it is advisable to use current transformers with five ampere shunts in the secondary circuit, as is the general practise.

The shutter mechanism construction makes it possible to use a special film holder having a long film, in a magazine, on which several exposures can be taken without reloading, and without the help of a dark room. It would be impossible to use such a film for transients unless the oscillograph shutter mechanism caused the exposure to begin at the same part of the revolving drum, each time, as is the case with this instrument.

The operator can make all oscillograph adjustments and all connections with the apparatus to be tested, at his leisure; then when all is ready he has but to *depress the control switch and everything works automatically.* In fact, the operator could be miles away from the oscillograph, and by the pressure of a single button the whole apparatus could be made to function perfectly.

This oscillograph has been used to operate, successively, a closing switch, which caused an abnormal current to build up through an inductance, then to trip a circuit breaker and operate the polar, multi-exposure, high-speed camera[2] so that the latter would make a series of photographs of the rapidly extinguished arc, while the oscillograph made a complete record of the building up and rupture of the current, and the accompanying voltage surges.

2 J. W. Legg, *Electric Journal*, December, 1919

Summary of the Special Features of the Portable Commercial Oscillograph

1. Special compactness of apparatus, including the series electromagnet galvanometer.
2. Use of an incandescent lamp with special arrangements to obtain very great intrinsic brilliancy.
3. Mechanically operated focal plane shutter, which always starts exposures at the beginning of the film.
4. Remote-control switch to cause transient to appear at any desired part of the film.
5. Trip magnet to operate remote-control switch and shutter immediately after abnormal voltage is applied to the incandescent lamp.
6. Lamp extinguishing switch to prevent the filament from being destroyed.
7. Self-contained storage battery to supply galvanometer field.
8. Switch for placing ammeter in galvanometer field or battery charging circuits.
9. Element resistances and control panel for commercial voltages.
10. All the above apparatus mounted in a single case 13 by 14 by 25 inches over all, and weighing but 82 pounds.
11. Transformer, for 110 or 220 volts, 20 to 70 cycles, supply for incandescent lamp, trip magnet, and induction motor operation.
12. Switches for motor, transformer and lamp control.
13. Induction motor with back gear and step pulley arrangement for driving photographic drum at uniform speed over a great range of speeds.
14. This *portable commercial oscillograph* arranged in but two units which together weigh but 135 pounds, including storage battery and transformer.

THE ELECTRIFICATION OF STEAM RAILROADS

One of the most important subjects to come before the recent N. E. L. A. Convention was "The Electrification of Steam Railroads," and the report of the Committee was submitted at the third general session, Friday, May 21, by Mr. Frank M. Kerr, of the Montana Power Company, of Butte, Montana, who is Chairman of the Committee. An abstract of Mr. Kerr's elaborate study on the subject is as follows:

"If all the steam railroads in the country were electrified with power furnished from large steam-generating electric stations, the total fuel required would be equivalent to 53,500,000 tons of coal, as against the actual figure for railroad coal used during the year 1918, of 175,000,000 tons. Thus, by electrification of the railroads, 122,500,000 tons of coal would have been saved.

"The Chicago, Milwaukee & St. Paul Railway and the Montana Power Company have demonstrated in Montana the entire practicability and great superiority of electric power for the operation of a heavy trunk-line railway, by more than four years of 100 per cent operation. Four-thousand-ton trains go up and down heavy mountain grades under perfect control, at speeds never known before and with a regularity which is phenomenal."

"The change from steam to electric operation means more than a mere change in type of locomotive used. It means a change in the entire conception of the art of railroad transportation."

"In short, by adopting electrification, the railroad company is relieved entirely of the business of generating power, and is enabled to concentrate on its main business of transportation." * * *

"The higher speed at which cars can be hauled over a road with electric operation allows the same amount of freight to be handled with a considerably smaller number of cars. This is such an important item that it is safe to say that if all the roads in the country were electrically operated at the present time there would be no car shortage."—*N. E. L. A. Bulletin.*

A Dynamometrical Comparator

A Differential Dynamometer for Accurate Comparison of Alternating and Direct-Current Strengths

BY EDY VELANDER

Electrical Engineering Research Division; Massachusetts Institute of Technology

ACCURATE ALTERNATING-CURRENT MEASUREMENTS.

IN a direct-current measuring instrument, the deflection is usually proportional to the strength of the current to be measured, and it is also proportional to the strength of a magnetic field, produced by permanent magnets. In the corresponding alternating-current instrument, the magnetic field must ordinarily be produced by the measured current itself, and the deflection will therefore be inherently quadratic with respect to the measured quantity. In a thermal instrument, the heating effect of the current is observed, and the scale is likewise quadratic. This correspondingly holds for electrostatic alternating-current instruments. With this inevitable second-power relation follows uneven scale divisions, and poor sensitivity at low values, two circumstances which have a decidedly detrimental effect upon the accuracy of alternating-current measurements. In work requiring a high degree of precision, some indirect method is therefore often employed, and the alternating-current measurement is reduced to a direct-current measurement by use of an intermediate apparatus, which may be generally called a *comparator*. By aid of the comparator some effect of the alternating current to be measured is either observed, through direct-current measurements, or neutralized by means of a direct current, the exact value of which may be determined with the extremely high accuracy of the direct-current potentiometer.

Thermal Comparators. Very often the comparator is based upon an observation of heating effects. So in the common "thermocouple," where the temperature of a heater is observed by means of a thermocouple, and millivoltmeter or potentiometer, and also in the bolometer, where the change in resistance of the heater is observed in a d-c. bridge, and taken as a measure of the strength of the alternating current. Both of these instruments must be calibrated on direct current.

In the ordinary thermocouple, mutual interactions between the a-c. circuits and the auxiliary d-c. system are avoided by using only a one-point interconnection. In an improved form of the bolometer[1] a double balance in a Wheatstone bridge is used for the same purpose. The heater is built in the form of a quadrilateral with equal sides, the direct current entering and leaving by two opposite corners, while the alternating current to be measured is supplied at the two other corners. Since the four arm-impedances are all alike, the bridge formed by the heater will be in a double balance, and there will be no a-c. potential difference between the d-c. terminals, nor any d-c. potential difference between the a-c. terminals of the bridge, and the two thus will be electrically independent. In a similar instrument, the barretter[2] condensers are used to restrict the direct current to its system, while choking coils prevent alternating current from straying into the d-c. system.

The Barbagelata Differential Current Balance. The principles of an ingenious dynamometrical comparator, where the Wheatstone bridge is used for separating alternating and direct currents, were suggested by Barbagelata in 1908[3]. In a Kelvin current balance, the two fixed and two movable coils are arranged in a bridge, as shown in Fig. 1. Connection is made to the moving part of the balance through the pivot, at *a*, and also through mercury cups, or flexible leads, at *b* and *d*. Alternating current is supplied to the system at the

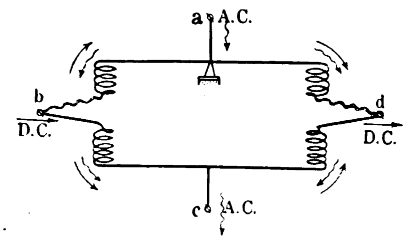


FIG. 1—THE BARBAGELATA DIFFERENTIAL CURRENT BALANCE

points *a* and *c*, while the direct current enters at *b* and leaves at *d*. If an electrical balance is maintained, one-half of the direct current will pass through the moving part, and one-half through the fixed part of the balance. Similarly the alternating current will divide evenly over the left and right hand parts of the system, but due to the bridge feature, no interactions will occur between the a-c. and d-c. systems. It will be seen, from an inspection of the figure, that if the alternating current and the direct current have the same directions in the upper coil on either side, they will flow in opposite directions in the lower coil, and vice versa. Their torques therefore will *oppose,* and at a certain value of d-c. strength the resultant torque will be zero. It is also immediately seen that this instrument is an absolute comparator in the sense that no calibration is necessary. Since alternating current and direct current flow in the same coils, equality of torque means equality of r. m. s. values, without reference to any instrument constants. (In a heavy-current

1. See reference at end of paper.

balance with few turns of large cross-section conductor, uneven current distribution may cause deviations from a one-to-one ratio.)

The New Dynamometrical Comparator. Independently of the Barbagelata differential balance, a dynamometrical comparator, working on very similar principles, has been developed at the Electrical Engineering Research Division of the Massachusetts Institute of Technology, according to a suggestion from the U. S. Bureau of Standards. The new instrument was constructed by Mr. C. O. Gibbon[4], and in its first form was described by him[5]. It is built in the form of a sensitive electrodynamometer, and contains a system of fixed field coils, and a strip-suspended oil-damped moving coil. The deflections are observed by the mirror and beam-of-light method. (For a detailed description of the apparatus see Mr. Gibbon's paper).

To make this instrument work as a comparator, the fixed and moving coils were connected as tow arms of a bridge, as indicated in Fig. 2, the other tow arms of the bridge being made up of an identical set of coils, forming a "dummy" instrument, which served only for obtaining the bridge-balance.

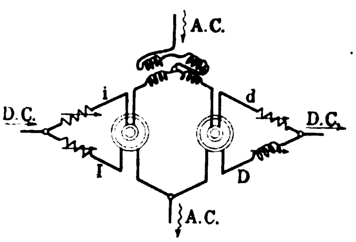


FIG. 2—THE GIBBON DIFFERENTIAL DYNAMOMETER

Mr. Gibbon gives as conditions for the double balance:

$$R_I = R_i = R_D = R_d, \quad (1)$$
$$L_I = L_D : L_i = L_d, \quad (2)$$
and $$M_{iI} = M_{dD}. \quad (3)$$

The last condition was satisfied by adjusting the fixed and moving coils at right angles to each other, making $M_{iI} = M_{dD} = 0$. The equality (1) involves three resistance-adjustments, made on three variable resistances, one in each of three arms, and the conditions (2) were obtained by means of a mutual inductance and a small variable inductance, as indicated in the figure.

The great number of necessary adjustments, and the difficulty to obtain accurate checks upon each one during the use of the instrument, made the practical application of the comparator in its earlier form somewhat cumbersome. However, from some tests made with the apparatus in this temporary bridge-arrangement it became at once clear that this differential dynamometer possessed some very remarkable properties, and in particular that it permitted the measurement of alternating currents of a few hundredths of an ampere with an accuracy far beyond that of any other available instrument.

Second Stage of Development. In connection with some research in alternating-current potentiometry the writer therefore undertook to study the instrument with a view to adapting it for accurate current measurements in the laboratory[6]. It was found that by making certain changes in the connections, a considerable simplification could be effected so that the number of adjustments, necessary to make and check during the use of the apparatus, could be reduced to one. By assembling all auxiliary parts, needed for the adjustment and manipulation during use, into one box, which could be placed within easy reach of the observer, the use of the comparator for actual measurements was still more facilitated. In the following this second step of development will be described, by which the instrument was carried from the experimental stage into the ranks of useful laboratory tools. The development work and tests here described were carried out in the laboratories of the Electrical Engineering Research Division of the Massachusetts Institute of Technology, and the writer is much indebted to the Director of this Division, Dr. A. E. Kennelly, for the encouragement and the valuable suggestions he has given in the course of the work.

Simplified Connections. It is not essential that all four arms of the comparator-bridge shall contain inductance since the d-c. distribution is not affected by its presence. By interchanging the points of supply of d-c. and a-c. in Fig. 2, the dummy can therefore be omitted, and replaced by two non-inductive magnanin resistances adjusted once for all to a certain value. The big field coils of the instrument, if wound with the same resistance as the small moving coil, will have a much bigger inductance than the latter, and as a rule will also have different cooling conditions, so that they are liable to change resistance due to Joulean heat in another proportion than does the moving coil. For similar reasons the change in apparent resistance and inductance which occurs at higher frequencies, due to skin effect and coil capacity, will as a rule be different for the small coil and for the larger one. Therefore, in order to get, in one stroke, an approximate resistance—and inductance-balance, and also symmetrical conditions, not only thermally, but with respect to high-frequency disturbances as well, the dummy was not thrown out, but was instead transferred to the instrument side of the bridge, and connected so that each of the two working arms of the bridge contains one big and one small coil, as shown in Fig. 3. The two remaining arms of the bridge are formed by the ratio-coils N_1 and N_2, which are bifilarly wound of *Ia . Ia* resistance wire. In the existing instrument, the sum of the resistances of the small and the big coil was a little less than 250 ohms, and the ratio-coils N_1 and N_2 were therefore accurately adjusted to this value.

Astatic Double-Instrument. The use of a dummy clearly represents a waste of power, and for the same sensitivity doubles the instrument resistance. In

future new-construction, the instrument therefore should be built either with two as nearly as possible identical coils, or the dummy should be incorporated as a working part of a double-instrument with two equal systems of field coils, and with two identical moving coils put on the same suspension. It is also conceivable that good results could be obtained in a double instrument with one active coil in each arm, whereby the coils N_1 and N_2 could be omitted and the total resistance thus halved. By this arrangement, however, the simplicity in manipulation would be sacrificed, which follows the introduction of constant-resistance coils in two arms.

In its present form the apparatus is strongly susceptible to stationary magnetic fields, such as the field of the earth, and direct-current stray fields, as well as to alternating magnetic fields of the same frequency

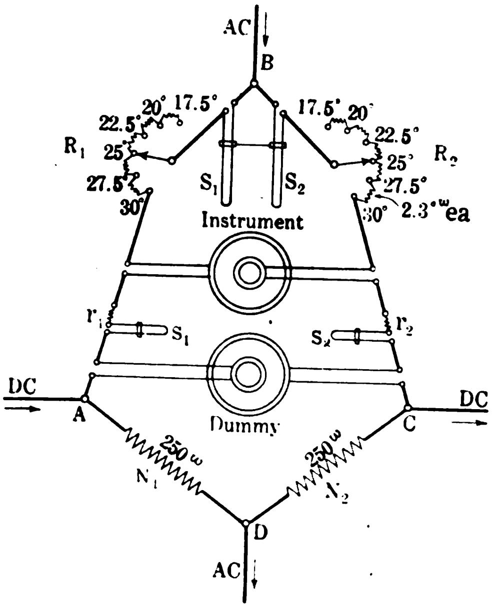


FIG. 3—THE NEW CONNECTIONS OF THE COMPARATOR

as the measured current. The field coils also send out powerful stray fields which may cause disturbances in other apparatus. By proper connection of the coils in a double instrument of suggested form, the conditions of a complete astaticism could be approached, which would tend to eliminate the mentioned inconveniences.

Adjustments. Considering Fig. 3, we find that the following relation must hold in order that the direct current shall split into two equal parts:

$$R_1 + R_2 = N_1 + N_2 \qquad (4)$$

Corresponding condition for the splitting of the alternating currents into two parts, equal in amplitude and phase, is in complex notation

$$R_1 + N_1 + j\,\omega\,L_1 = R_2 + N_2 + j\,\omega\,L_2 \qquad (5)$$

or, since $N_1 = N_2$,

and
$$\begin{cases} R_1 = R_2 & (6) \\ L_1 = L_2 & (7) \end{cases}$$

Mutual inductance between arms 1 and 2 will in this case evidently not affect the current distribution.

Now, if

$$R_1 : R_2 = N_1 : N_2 \qquad (8)$$

or again

$$R_1 = R_2 \qquad (6)$$

then there will be zero d-c. potential difference between the points B and D. This, however, is not essential, since the direct current may easily be cut off from the a-c. system by means of blocking-condensers at these terminals.

In order that no alternating current shall enter the d-c. system, we should have

$$(R_1 + j\,\omega\,L_1) : N_1 = (R_2 + j\,\omega\,L_2) : N_2 \qquad (9)$$

Since $N_1 = N_2$, this equation reduces to conditions (6) and (7).

The condition (7), or $L_1 = L_2$, may be easily adjusted once for all by changing the inductance of either arm.

However, since the two instrument arms of the bridge contain copper resistances, it is necessary to have some temperature compensation, such as is provided by the dial rheostats shown in Fig. 3. Each dial-step corresponds to a 1 per cent resistance increase, or a 2.5 deg. cent. rise in average temperature of the system. The slide-wires S_1 and S_2 provide for a continuous variation between these steps, while r_1, r_2 and s_1, s_2 serve to adjust, once for all, the 20 deg. cent. resistance of either arm to exactly 250 ohms.

Errors Due to Inaccurate Adjustments. If the direct current i splits into two parts, i_i in the instrument side, and i_n in the resistance side of the bridge, then the d-c. torque, being produced by i_i only, will be have the value

$$T_{dc} = K \,.\, i_i^2 \qquad (10)$$

where K is a certain instrument constant.

If the splitting is correct, so that i_i is just one half of i, we have

$$T_{dc}' = \frac{K\,i^2}{4} \qquad (10a)$$

On the other hand, if the alternating current I splits in two parts I_1 and I_2, the a-c. torque will be

$$T_{ac} = K \,.\, |\,I_1\,I_2\,| \cos\,(I_1, I_2) \qquad (11)$$

or, when I_1 is equal to, and in phase with I_2,

$$T_{ac}' = \frac{K\,I_0^2}{4} \qquad (11a)$$

where the r. m. s. value of the current I is denoted by I_0.*

Now, when the compensator shows zero deflection,

$$T_{ac} = T_{dc} \qquad (12)$$

and thus

$$i = I_0 \qquad (13)$$

*We consider here only the case of a purely sinusoidal current. The effect of harmonics has been to some extent treated by Gibbon[5]. Just as the ordinary electro-dynamometer, this instrument will give r. m. s. values, independent of wave-form. The analysis given above may be applied to each and any of the components if the measured current is of a complex wave-form.

The direct current i is therefore exactly equal to the r. m. s. value of the alternating current, independently of the constant K. However, errors may here occur, either by a misadjustment in the d-c. splitting, so that (**10a**) is not true, or by a faulty a-c. adjustment, causing a deviation from equation (**11a**).

If a misadjustment is made in the d-c. splitting condition (**4**), since $i_i + i_n = i$, we may write

$$\begin{cases} i_i = \dfrac{i}{2}\,(1 + \epsilon) \\[2ex] i_n = \dfrac{i}{2}\,(1 - \epsilon) \end{cases} \tag{14}$$

The d-c. torque then will be

$$T_{dc} = \frac{K\,i^2}{4}\,(1 + \epsilon)^2 \tag{15}$$

and an error

$$\Delta\,T_{dc} = T_{dc}'\,(2\,\epsilon + \epsilon^2) \tag{16}$$

will result.

If a similar misadjustment is made in the a-c. splitting condition (5), the relative error ϵ may be a

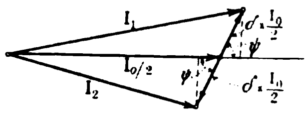


Fig. 4—An Error in the A-C. Splitting Condition

vector, say $\delta \angle \Psi°$, and we get, in accordance with Fig. 4, and in analogy with (**14**):

$$\begin{cases} I_1 = \dfrac{I}{2}\,(1 + \delta \angle \Psi) \cong \dfrac{I}{2} \times (1 + \delta \cos \Psi) \\ \qquad\qquad \angle \tan^{-1}(\delta \sin \Psi), \\[2ex] I_2 = \dfrac{I}{2}\,(1 - \delta \angle \Psi) \cong \dfrac{I}{2} \times (1 - \delta \cos \Psi) \\ \qquad\qquad \angle - \tan^{-1}(\delta \sin \Psi). \end{cases} \tag{17}$$

The a-c. torque then will be

$$T_{ac} = \frac{K\,I_0^2}{4}\,(1 + \delta \cos \Psi)\,(1 - \delta \cos \Psi) \times \cos\,[\,2 \tan^{-1}(\delta \sin \Psi)\,] \tag{18}$$

and the absolute value of the error

$$|\,\Delta\,T_{ac}\,| = T_{ac}'\,(1 - \delta^2 \cos^2 \Psi)\,(1 - 2\,\delta^2 \sin^2 \Psi + \ldots)\,]\,| \tag{19}$$

We may therefore safely put

$$|\,\Delta\,T_{ac}\,| < 3\delta^2 . T_{ac} \tag{20}$$

Expressing eq. (**16**) and (**20**) in words, we may accordingly say, that a misadjustment of 1 per cent in the d-c. splitting conditions will give rise to a little more than 2 per cent error in the current equality, while a misadjustment of 1 per cent in size in the a-c. balance will affect the comparator reading by less than 3 parts in ten thousands. Considering that each step in the dial rheostats represents 1 per cent of R_1, that is, 0.5 per cent of the sum $R_1 + N_1$, the conclusion is that even such a rough misadjustment as one full step on these rheostats will give an error of measurement that is less than 0.0075 per cent. It is therefore permissible to adjust once for all $R_1 = R_2$ and only occasionally check this adjustment. On the other hand, the condition $R_1 + R_2 = N_1 + N_2$ must be very accurately maintained and since R_1 and R_2 are liable to change with room temperature, and with load, facilities must be provided for checking this adjustment at any time during the use of the comparator. In order not to interfere with the adjustment $R_1 = R_2$, the dial rheostats while adjusting the condition $R_1 + R_2 = N_1 + N_2$, should always be

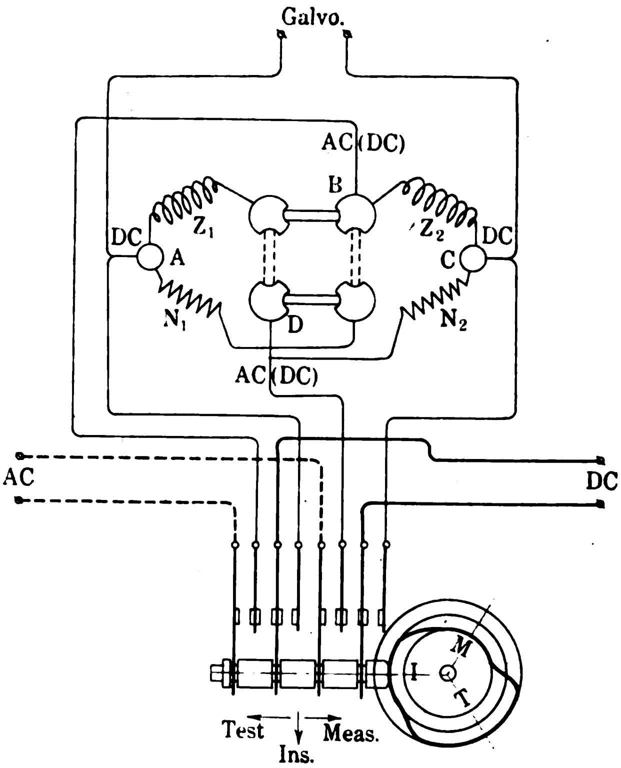


Fig. 5—Plug-contacts and Selector Switch

moved symmetrically, and for similar reasons the runners on the slidewires S_1 and S_2 are mechanically interconnected.

Manipulation. To facilitate the resistance-adjustments the bridge-arms are connected to four plug-contacts, as indicated in Fig. 5, and a four-pole double-throw contact-spring switch is provided, whose mechanism is schematically shown in the figure. For the sake of clearness the contact-plugs are drawn as interconnecting bars. The full-drawn bars indicate the working position. With the switch in position M (Measurement) the bridge will then appear as shown in Fig. 3.

By turning the switch over to position T (Test), direct current is impressed across terminals A and C in Fig. 3, while the a-c. system is disconnected. The

condition $R_1 = R_2$ then may be adjusted to by means of a d-c. galvanometer, as indicated in Fig. 6 a.

If the connecting plugs are changed to the position indicated by dotted bars in Fig. 5, the bridge will take the form of Fig. 6 b. If a balance in the d-c. galvanometer is obtained by increasing or decreasing R_1 and R_2 by equal amounts, the following relation will hold:

$$R_1 : N_1 = N_2 : R_2. \qquad (21)$$

For reasons given above, we have allowed, in the previous adjustments, a certain inaccuracy, so that R_1 may not be exactly equal to R_2. If we denote by R' the arithmetical mean of R_1 and R_2, the condition of exact d-c. splitting may be written

$$2\,R' = N_1 + N_2, \qquad (22)$$

while the two resistances will be, say,

$$\begin{cases} R_1 = R'\,(1 + k), \\ R_2 = R'\,(1 - k). \end{cases} \qquad (23)$$

Introducing these notations in eq. (**21**) we get at a balance

$$R'\,(1 + k) \times R'\,(1 - k) = N_1 N_2, \qquad (24)$$

or

$$R'^2 = \frac{N_1 N_2}{1 - k^2} \qquad (25)$$

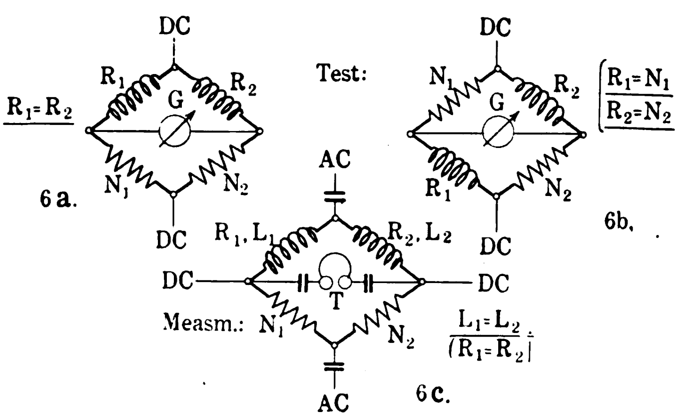


Fig. 6, a, b, c—Connections for Measurement and Test

Therefore, even if an exact adjustment of the bridge in Fig. 6 b is obtained, there may still remain a slight deviation from eq. (22). If the two resistances R_1 and R_2 are just equal, the deviation will vanish. In any other case, the relative error in R'^2 being k^2, there will be an error $\frac{1}{2}k^2$ in the adjustment of R', which results, by equation (**16**), in an error of measurement twice as great, or k^2. Allowing a deviation $2\,k$ of 1 per cent between R_1 and R_2, we shall have $k = 0.005$, and the resulting error in measurement—25 parts in a million. Although the described method of adjusting the instrument does not in general lead to a perfectly correct adjustment, the errors will in any practical case be entirely insignificant, and the method may therefore be recommended because of its convenience.

The a-c. balance condition $L_1 = L_2$ may easily be arrived at by use of a pair of head-phones, with the instrument connected for measurement, as Fig. 6 c suggests. In reality the adjustment was obtained by slightly changing the position of one field coil in the dummy with respect to the other, whereby the total inductance of the arm was varied. It has been experimentally ascertained that such an adjustment, made at a low frequency, will hold true at least up to 2500~.

The one and only adjustment that has to be made, or tested, during run, therefore, is represented by Fig. 6 b. It is to be noted here, that the necessity of using a d-c. galvanometer for this adjustment does not in general imply any appreciable complication, since a d-c. potentiometer is usually employed for the accurate determination of the compensating direct current, and a galvanometer is therefore already included in the outfit.

Correction-Method. It is possible, by making double use of this potentiometer, to avoid all adjustments during run and replace them with arithmetical operations representing experimentally determined corrections to be applied to the measured values of direct-current strength, in order to obtain the actual alternating-current value at balance when condition (4) is not fulfilled. The corrections may be determined by plugging the bridge as Fig. 6 b shows, and measuring with potentiometer the potential difference between the two terminals marked "Galvo." This potential difference, v, is the difference between the drops along R_1 and N_2:

$$v = \frac{R_1\,(R_2 + N_2) - N_2\,(R_1 + N_2)}{R_1 + R_2 + N_1 + N_2}\ .\ i. \qquad (26)$$

Putting $N_1 = N_2 = N$ and using equations (**23**), we obtain

$$v = \frac{R'^2\,(1 - k^2) - N^2}{2\,(R' + N)}\ .\ i \qquad (27)$$

$$= \tfrac{1}{2}\left[\, R' - N - \frac{R'}{N + R'}\ .\ k^2 R' \,\right] .\ i \qquad (27a)$$

From equations (**10** a) and (**11** a) may be derived a general expression for the true alternating-current strength I_0:

$$I_0 = 2\,{}_{a}i = i \times \frac{2\,(N_1 + N_2)}{R_1 + R_2 + N_1 + N_2}\ ; \qquad (28)$$

whence, in the new notation.

$$I_0 = i - i \times \frac{R' - N}{R' + N}\ . \qquad (29)$$

Inserting the value of $R' - N$ from eq. (**27** a) we get

$$I_0 = i - \frac{2\,v}{R' + N} - k^2 \left(\frac{R'}{R' + N}\right)^2, \qquad (30)$$

From the form of eq. (**29**) it is evident that v must be counted positive when R' is greater than N, which is the case that would occur in practise, due to heating effects in the coils. The direct current is then greater than the alternating current and the correction consequently negative.

For all practical purposes R' may be written $= N$

in the correction term, and the last term may be neglected. The result then is the following extremely simple formula:

$$I_0 = i - \frac{v}{N} \ . \tag{31}$$

A more exact formula (the k^2-term only neglected) is

$$I_0 = i - \frac{v}{N + v / a} \tag{31a}$$

As a rule, however, (**31**) may be used, and the correcting becomes very simple. We have here neglected the change in i which may occur when the bridge is plugged over from the position 6 c to 6 b. Clearly, such a change will be very small and affect only the correction term and to a very small extent.

In cases where the comparator is used with varying current strength of such values that the heating effects are appreciable, the correction method probably will be much handier than the regular adjustment method. In determining the corrections it becomes unnecessary to await steady thermal conditions. Each observation on the comparator may instead be interpolated between two determinations of the correction, the mean of which is used.

Precautions. In the use of a dynamometric comparator of non-astatic type there are certain precautions to be taken so as to avoid disturbances from the earth's field. The instrument is conveniently set up with the plane of the moving coil perpendicular to the horizontal component of magnetic intensity. A compensating magnet, suitably placed, often does good service for eliminating the last trace of disturbance. In the control-box, four plug-contacts are provided for reversing the moving coil. The instrument may be tested for constant and alternating magnetic stray fields by passing, correspondingly, direct respectively alternating current through the moving coil, and observing, if any change of zero occurs upon reversal of the moving coil. During this test the instrument field-coil arm s opened by removing one of the bridge plugs.

When the comparator deflects, its effective inductance, which is normally about 80 millihenrys, changes quite appreciably. In work with resonant circuits an instability may therefore occur. Such instability may always be eliminated by reversing the moving coil. When the instrument inductance must be accurately known, the coils are so adjusted that their axes form a 90 deg. angle in the zero or balanced position. Perpendicularity may be reached by passing a relatively strong alternating current through the field coils, and turning the suspension until no deflection occurs upon short-circuiting the moving coil with one of the reversing plugs.

Accuracy and Limitations. The foregoing analysis clearly shows that the bridge-adjustments necessary for correct indications in the comparator easily may be carried to a point where the results have at least a four-figure accuracy. When the instrument is employed to measure an alternating current of 20 milliamperes, a change in current of 1 per cent causes a deflection of 65 mm. (2¼ in.) at a one meter scale distance. At lower currents the instrument is less sensitive, but a comparator may be designed for any current range by choosing the proper number of turns in the coils, etc. Twice the sensitivity would be obtained in an astatic double-instrument, as suggested above, and by building the comparator in the form of a torsional balance an extremely high sensitivity could be reached, permitting the accurate measurement of alternating currents counted in microamperes.

An upper limit is put to the current range of any particular instrument by the heating effects in the coils, and at lower frequencies by mechanical vibrations in the moving system, probably due to unbalanced magnetic pull. The useful frequency range is limited by the high inductance, and by disturbances due to capacity in the coils.

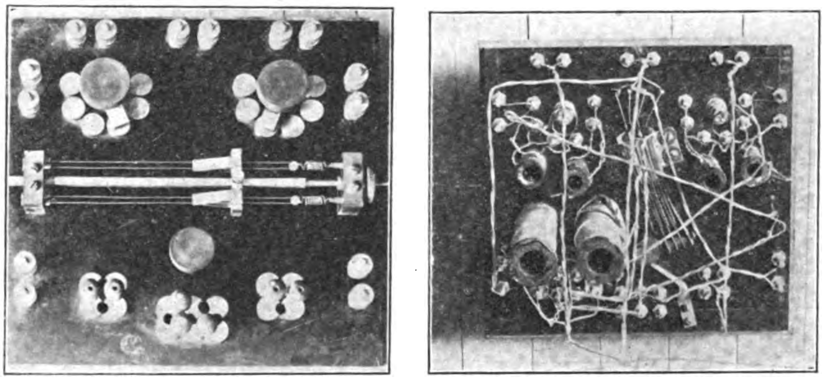


Fig. 7, a & b—Showing the Control-box
a is a view of the top, and *b* shows the inside of the box, seen from below

It is interesting to note, that since this form of comparator probably represents the most sensitive and accurate method of determining the strength of alternating currents of the order of magnitude in question, which is known at the present time, there appears to be no way of experimentally checking its accuracy by comparison with other instruments. It is to be expected that at higher frequencies errors will occur to capacity effects in the coils, but attempts to ascertain the existence of such deviations by direct comparison with an accurate thermocouple gave negative results for frequencies up to 2500 p. p. s.

The Design of the Control Box. Fig. 7a shows the appearance of the control-box as viewed from above, and Fig. 7b is a picture of the interior of the box. The two dials and slide-wires on the top are easily identified, and to the left are the four plug contacts for the bridge while the four plug contacts to the right serve for the reversal of the moving coil. The six plugs in the middle of the lower edge are intended for connection to a constant-impedance shunt on the moving coil, a refinement which did not appear necessary with the

instrument as built, since it could well stand 90 deg. deflections without damage to the sturdy suspension.

Practical Applications of the Dynamometrical Comparator. Fig. 8 will give an indication how the comparator may be used for the accurate calibration of a shunted thermocouple at various frequencies. A d-c. potentiometer is used for determining the thermo-e.m.f. of the couple, and also, by observing the drop across a standard resistance, for measuring the compensating current in the comparator. The same potentiometer may be employed, in the correction-method, for determining the quantity v (**31**) and the instrument correction.

An interesting suggestion regarding the possibility of increasing the range of the instrument was made by Mr. Varley[7] who proposed to measure heavy alternating currents by means of much weaker direct currents. For this purpose auxiliary d-c. field coils would have to be arranged outside the bridge proper, so as to aid the ordinary field coils in building up the counter-

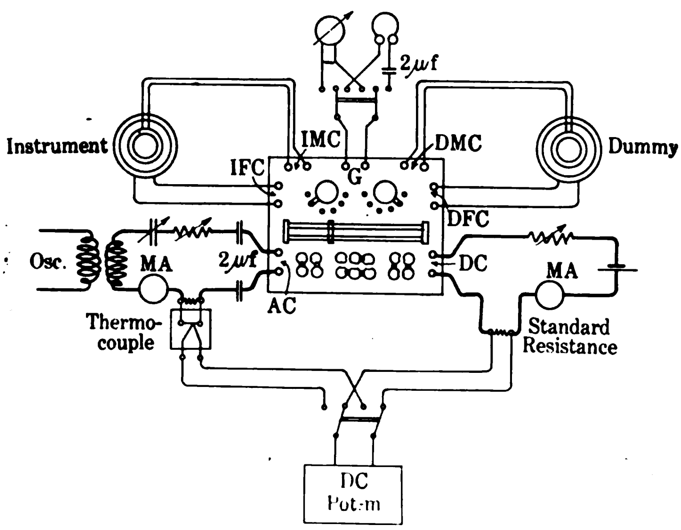


Fig. 8—The Dynamometrical Comparator and its Control Box Employed for Calibrating a Shunted Thermocouple

acting d-c. torque. The instrument would then have to be calibrated, and the very important feature of automatic equality between a-c. r. m. s. value and compensating d-c. strength, without reference to instrument-constants, would have to be given up.

Until very recently there was no need, at least not for work within the telephonic frequency-range, for an alternating-current measuring instrument of any such accuracy as may easily be obtained by this dynamometrical comparator. Since there was no sufficiently constant source of alternating current available, current measurements of high accuracy were of no use. However, with the advent of the three-electrode high-vacuum tube oscillator as a laboratory source of audio frequency current, the situation has changed. When fed from storage batteries the triode oscillator gives an output of four-figure constancy to amplitude as well as to output frequency. The need for an instrument of comparable accuracy has thus arisen, and the differential dynamometer will no doubt find many applications in the new technique of accurate alternating-current measurements which is growing up on the basis of the triode oscillator as a source of current. When used for instance in conjunction with an alternating-current potentiometer for adjusting the potentiometer current to a certain fixed value, the manipulation of the comparator is very simple. In such a case it is evidently not necessary to use a regular potentiometer with the outfit, but a once for all adjusted resistance and a standard cell, will equally well serve for checking of the compensating current.

Summary

1. Due to inherently lower precision of alternating-current measurements, more accurate results are often obtained in transferring, by means of a comparator, the alternating-current measurements into direct-current measurement of related type.

2. A dynamometrical comparator, acting as a differential dynamometer, with its coils connected as two arms of a Wheatstone bridge, was constructed by Mr. C. O. Gibbon, in the Electrical Engineering Research Division of the Massachusetts Institute of Technology.

3. Even in its first experimental form this instrument proved capable of a most remarkable sensitivity and accuracy.

4. In the hands of the present writer, the dynamometrical comparator has reached a second stage of development. By the introduction of a special control-box the manipulation has been much simplified. Means have also been provided for the quick and accurate adjustment of the comparator-ratio at any time during use of the apparatus for measuring purposes.

5. An analysis of the main sources of error shows that the accuracy of the instrument is extremely high, the readings being reliable to within a few hundredths of a per cent.

6. The comparator has very successfully been applied to various types of practical current measurements. In fact, this instrument, in conjunction with a direct-current potentiometer, seems to offer the most accurate means which are known at the present time, for the determination of the r. m. s. value of alternating currents of the order of 5 to 50 milliamperes, at frequencies up to about 2000 p. p. s.

7. Already in its present form the dynamometrical comparator thus has proved to be a very useful laboratory instrument. Certain definite suggestions are made, however, concerning further improvement in the apparatus.

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with which is incorporated the PROCEEDINGS of the A. I. E. E.

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PACIFIC COAST CONVENTION

The Ninth Annual Pacific Coast Convention of the A. I. E. E. will be held in Portland, Oregon, July 21-24, 1920, under the auspices of the Portland Section. Headquarters at the Multnomah Hotel.

A program has been arranged as follows:

Wednesday, July 21

9:30 A. M.

1. *Address* by President Calvert Townley.
2. *Factors Controlling the Design and Selection of Suspension Insulators*, by W. D. A. Peaslee, Electrical Engineer, Jeffery-Dewitt Insulator Company.

2:00 P. M.

3. *Unit Voltage Duties in Long Suspension Insulator Strings*, by Professor Harris J. Ryan and H. H. Henline of Leland Stanford Jr. University.
4. *Electrical Characteristics of the Suspension Insulator at the Higher Voltages*, by F. W. Peek, Jr., Consulting Engineer, General Electric Company, Pittsfield, Mass.

7:30 P. M.

Automobile tour over scenic boulevards of the city.

Thursday, July 22

9:30 A. M.

5. *Electrification of Railroads*, by Reinier Beeuwkes, Electrical Engineer, C. M. & St. P. Railroad.
6. *Bridge Methods for Alternating-Current Measurements*, by D. I. Cone, Engineering Dept., Pacific Telephone and Telegraph Company.

2:00 P. M.

7. *Sawmill Refuse, Fuel Oil and Pulverized Coal*, by Darrah Corbet, Chas. C. Moore and Company.

7:30 P. M.

General discussion on Institute Welfare.

Friday, July 23

9:30 A. M.

8. *Power Factor Correction on Distribution Systems*, by D. M. Jones, General Electric Company, Schenectady, N. Y.
9. *Use of Special Steels in Pressed Steel Transmission Line Fittings*, by L. R. O'Neill, Chief Engineer, Maryland Pressed Steel Company.

In addition to the presentation of the papers scheduled above the Convention Committee has arranged for various entertainment features including a Golf Tournament for the John B. Fisken Cup to start at 1 p.m. on Friday, a trip over Columbia River Highway starting at 2 p.m. on the same day and followed by a banquet at the Crown Point Chalet at 7 p.m.

Saturday, July 24

Tours of inspection to the steam and hydroelectric plants of the Portland Railway, Light and Power Company and the Northwestern Electric Company and to other points of interest in and around Portland are arranged for Saturday, July 24.

Special entertainment will be provided for the visiting ladies.

EDISON MEDAL PRESENTATION TO W. L. R. EMMET

A brief notice of the presentation of the Edison Medal to Mr. W. L. R. Emmet was given in the June JOURNAL which was published before the details of the meeting could be reported. The program consisted of addresses by Carl Hering, Chairman of the Edison Medal Committee; Past President, H. W. Buck; and the recipient, Mr. Emmet. Mr. Hering described the origin and history of the medal and said in part:

"In 1904 a group of twenty-four friends and former associates of Thomas A. Edison, forming an association known as the

W. L. R. EMMET

Edison Medal Association, initiated the thought of founding what was to be called the Edison Medal, for the purpose (as quoted from the Deed of Gift) 'of appropriately recounting and celebrating the achievements of a quarter of a century in the art of electric lighting, with which the name of Thomas Alva Edison is imperishably identified.'

"They subscribed to a fund of $5000 which is to be held in trust in perpetuity, and from the income of which a gold medal is to be executed, and a parchment certificate issued, which together with a part or the whole of the residue of this income, shall be awarded by a committee (to quote again from the Deed of Gift) 'to some one resident of the United States of America

and its Dependencies, or of the Dominion of Canada, for meritorious achievement in Electrical Science or Electrical Engineering or the Electric Arts, whenever in the judgment of said Committee a resident of either of said countries is properly deserving of such award.' The character of the achievement is to be stated on the certificate.

"This was thought by the founders and donors to be the most effective means to accomplish their object, which was that this Edison Medal (to quote again from the Deed of Gift) 'should, during the centuries to come, serve as an honorable incentive to

scientists, engineers and artisans, to maintain by their works the high standard of accomplishment set by the illustrious man whose name and features shall live while human intelligence continues to inhabit the world. * * * No change shall ever be made in such name."

"In the Deed of Gift the American Institute of Electrical Engineers agreed to undertake the awarding of this medal in accordance with the wishes of the donors, which function is characterized in that Deed as an 'extremely difficult and delicate task.' The Institute does so through a committee of 24 of its

members. The decision of this Committee is final, hence its responsibilities are great, and the rule has been to award this medal once a year. The medal itself was designed by James Earle Frazer; on its obverse side there is a portrait of Thomas A. Edison, and on its reverse side an allegorical conception entitled, 'The Genius of Electricity Crowned by Fame.'

"I presume that I am not divulging any confidential information of this committee in making the statement, which is so creditable to our country, that the 'difficulty' of its task mentioned in the Deed, has not been to find one who is worthy of the medal, but rather to decide which one of several shall be its choice for that year; let us hope, to the credit of this country, that this will continue to be the only difficulty of this Committee."

Mr. Harold W. Buck gave an account of Mr. Emmet's achievements in the Engineering field beginning with his entrance into the Navy in 1881. "After staying in the Navy for about two years, he went into business, and was occupied with various engineering and architectural work until the year 1887, when he joined the Sprague Electric Company, which was then coping with the electric railroad development in Richmond and later on in Harrisburg and other cities throughout the country.

"Mr. Emmet acted as Assistant Engineer of this Company and his first job was to go to Harrisburg to get the electric railroad system in that city working. He then went, in the same capacity, to Cleveland, Wichita and Kansas City, where he installed electric railway apparatus.

"In 1889 and 1890, he was sent to Pittsburgh, for the Sprague Electric Company, to oversee that installation, which was one of the largest electric railroad installations which had been made up to that time. There were 60 equipments, which at that time, was a very large installation.

"Mr. Emmet, with his characteristic determination, tackled this job, rewound the motors, reinsulated the coils, and devised new methods of attaching the brushes—devised and invented this method, which was really quite an historic development in electrical engineering, and he invented a new system of insulation for armature coils.

"In 1890, Mr. Emmet went with the Westinghouse Electrical Manufacturing Company for a short time, and in 1891, he associated himself with the R. D. Nuttall Company in Pittsburg, which was, at that time, developing electric railroad appliances. Mr. Emmet invented and patented several trolley devices and other electric railway supplies that were very successful.

"From there he went to Buffalo, as Engineer of the Buffalo Railway Company, and in 1891, he went to Chicago as the District Engineer of the Edison General Electric Company, which at that time had been formed, and he was engaged on construction work. In 1892, Mr. Emmet was transferred from the Chicago office to the New York office of the Edison General Electric Company, and started in there as engineer of the Foreign Department. From that position he was transferred to be engineer of the Lighting Department, and his most important professional work commenced at that time."

Mr. Buck then described at some length Mr. Emmet's work in the development of electric lighting, alternating-current distribution, air-blast transformers, oil circuit breakers, cable and generator insulation, steam turbines, electric ship propulsion, and his most important development, the mercury turbine, on which he is now engaged.

The Edison Medal and certificate of award were then presented to Mr. Emmet by President Townley, to which Mr. Emmet responded, expressing his appreciation of the honor conferred upon him. He also gave an interesting account of some of the more important activities of his career.

ANNUAL REPORT OF THE BOARD OF DIRECTORS

FOR THE YEAR ENDING APRIL 30, 1920

The annual report of the Board of Directors of the A. I. E. E. was presented at the annual business meeting of the Institute held in New York on Friday evening, May 21st, 1920.

This report consists of a brief summary of the principal activities of the Institute during the year, including abstracts of various reports submitted by officers and committees, covering their respective branches of work. Inasmuch as most of the matters of importance referred to in the report have been, or will be, covered in much more detailed form in the JOURNAL, the report will not be published in full herein, but any member

of the Institute may obtain a pamphlet copy upon application to the Secretary of the Institute.

The Board of Directors held ten regular meetings during the year; five of these were held in New York, one at the Lake Placid Club, N. Y., in June; one in Philadelphia in October; one in Chicago in January; one in Pittsburgh in March, and one in Boston in April; one Executive Committee meeting was held on April 27, 1920.

During the year President Townley attended many Institute and Section meetings including the Annual and Midwinter Conventions and meetings in Boston, Chicago, Detroit, Milwaukee, New York, Philadelphia, Pittsburgh, St. Louis, Schenectady and Toronto.

The report contains ample indication that the numerous committees of the Institute have resumed their pre-war activities. The increasing interest in the Institute's work is indicated by the large increase in membership during the year. With the demobilization of the army and navy completed, and industry returned to a peace basis, engineers are turning their attention to the zealous pursuit of their profession, which probably accounts largely for the fact that 2033 applications for membership were received during the year, which exceeds by 437 the number received during the previous year. The following tabulation indicates the present membership, and the additions and deductions during the year:

	Honorary Member	Fellow	Member	Associate	Total
Membership, April 30, 1919.	6	489	1467	8290	10,252
Additions:					
Transferred.....	....	18	106	....	....
New Members Qualified......	....	6	100	1717	....
Reinstated......	....	....	11	66	....
Deductions:					
Died...........	....	7	7	62	....
Resigned........	....	2	5	127	....
Transferred.....	....	....	12	112	....
Dropped........	....	6	43	548	....
Membership April 30, 1920........	6	498	1617	9224	11,345

Net increase in membership during the year.......................1093

The number of Sections has been increased during the past year by the addition of those at New York, Worcester, Mass., and Providence, R. I., and the number of Student Branches has been increased by the addition of Branches at the University of Wisconsin, and the School of Engineering of Milwaukee. The tabulation below indicates that the activities of the local organizations have returned to a condition corresponding to that prior to the war.

	For Fiscal Year Ending						
	May 1 1914	May 1 1915	May 1 1916	May 1 1917	May 1 1918	May 1 1919	May 1 1920
SECTIONS							
Number of Sections..	30	31	32	32	34	33	36
Number of Section meetings held.....	233	246	251	265	245	217	262
Total Attendance....	22,626	23,507	28,553	31,299	34,614	25,837	30.741
BRANCHES							
Number of Branches.	47	52	54	59	59	61	62
Number of Branch meetings held......	306	328	360	368	268	156	360
Attendance..........	11,617	12,712	15,166	16,107	10,683	6,441	16,827

The Finance Committee's report together with the General Balance Sheet and detailed Financial Statements of the certified public accountants who audited the Institute books are included in the report, and show that there has been a deficit of $3333.31 in the Institute's financial operations during the year; which, however, is considerably less than the original estimated deficit.

The reports of the Meetings and Papers Committee and the Publications Committee which were abstracted in the Directors' report are published in full herewith.

ANNUAL REPORT OF THE MEETINGS AND PAPERS COMMITTEE

FOR YEAR ENDING APRIL 30, 1920

The Meetings and Papers Committee has held a meeting every month except July and August. These meetings have been well attended and marked by much interest and discussion. A very large number of papers has been offered to the committee in the last year, more than could possibly be presented at the regular meetings of the whole Institute.

In order to make an opportunity to bring these papers before the members the M. and P. Committee recommended to the Board of Directors that the Chairman of each Section be made ex-officio a member of this committee in order that the Sections might be kept informed of the papers available and have a representative to ask for the assignment of appropriate papers for Section Meetings. The Board approved this suggestion and now each Section Chairman receives each month a list of papers available and is encouraged to ask for papers for presentation before the Section. So far the Sections have not taken full advantage of this arrangement.

The Committee has also found it advisable to recommend to the Publications Committee a number of papers that were of general interest but which could not be scheduled for meetings for lack of opportunity. A number of papers have thus been published without presentation at meetings.

In a great number of cases in the last year a Technical Committee has taken charge of a whole session or meeting of the Institute and presented a group of papers by different authors, all dealing with the same subject but from different points of view. The popularity of this scheme is one cause for the large number of papers presented.

Three conventions were held during the past year as follows:

The thirty-fifth Annual Convention at the Lake Placid Club, Adirondacks, New York, June 24-27, 1919.

The Pacific Coast Convention at Los Angeles, California, September 18-20, 1919.

The Mid-Winter Convention in New York, February 18-20. 1920.

Eight other Institute meetings were held during the year:, four in New York, and one each in Philadelphia, Chicago, Pittsburgh and Boston.

At the Conventions and other meetings referred to above, there were 52 papers presented upon various subjects as follows:

Traction 6, Electric Machinery 2, Power Stations 4, Electro-Physics 5, Standards 1, Electro-Chemistry 6, Protective Devices 3, Instruments 4, Lighting 5, Telephone and Telegraph 6, Transmission and Distribution 5, Miscellaneous 5.

REPORT OF THE PUBLICATION COMMITTEE

FOR THE YEAR ENDING APRIL 30, 1920

The Publication Committee was established for the first time during the present year by an amendment to the By-laws, in order to carry into effect the recommendations of the Development Committee relating to the Institute publications, as approved by the June 1919 Convention and subsequently by the Board of Directors. This committee has supervision of the monthly JOURNAL and the annual TRANSACTION of the Institute;

the functions of the former Editing Committee have been incorporated with those of the new Publication Committee.

The chief activity of this committee has been to put into effect the recommendation of the membership of the Institute that the monthly Proceedings be enlarged both as to scope and physical size and that it should serve as a medium of much more general information for the membership in addition to the customary Institute papers. This change was not easy to make during the past year, due to existing conditions of the publishing and related industries, including labor troubles and shortage of supplies. The change was inaugurated, however, with the issue of January 1920 and the committee submits the five numbers already published as a part of this report.

The committee is endeavoring to supervise the contents of the successive numbers so that the topics and branches of the profession represented will be diversified and so that in a reasonable sequence of numbers every interest will have been represented. The enormous increase in the cost of paper, printing and engraving has made it necessary for the committee to supervise its expenditures carefully in order to keep within the available funds, and therefore it has not yet been possible to do all that was hoped for and desired.

The appropriation for publications for the present fiscal year is 50 per cent greater than for any preceding year, thus more of the benefits of the Institute are being given directly to the membership in the form of publications than ever before, and this has been accomplished without any increase in the dues.

The committee wishes to express its appreciation of the encouragement it has received in the large number of unsolicited letters written by individual members expressing their approval and commendation of the new JOURNAL.

THE FEDERATED AMERICAN ENGINEERING SOCIETIES ORGANIZE

TO REPRESENT THE PROFESSION IN MATTERS OF COMMON INTEREST IN NATIONAL AND STATE AFFAIRS

In response to the call issued April 19, 1920 by the Joint Conference Committee representing the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, about 140 delegates representing 71 societies, having an aggregate membership of over 110,000, convened in Washington, D. C., June 3-4, 1920.

The Conference was called to order by the temporary Chairman, Richard L. Humphrey, Chairman of the Joint Conference Committee who outlined the history of the movement of which the meeting was the culmination, and sounded the keynote for the Conference.

An address of welcome on behalf of the District of Columbia and of the Washington Engineers, was delivered by Lt. Col. Charles W. Kutz, U. S. A., Engineer-Commissioner of the District of Columbia, which was responded to by the temporary Chairman.

Organization was effected through the election of Calvert Townley, Chairman, and John C. Hoyt, Secretary.

The following resolutions introduced by Gardiner S. Williams, embodying the fundamental principles of the comprehensive organization recommended by the Joint Conference Committee, were debated for a considerable portion of the morning session on June 3d:

RESOLVED, That it is the sense of this convention that an organization be created to further the public welfare wherever technical knowledge and engineering experience are involved and to consider and act upon matters of common concern to the engineering and allied technical professions.

RESOLVED, that it is the sense of this convention that the proposed organization should be an organization of societies or affiliations and not of individuals.

They were finally adopted without a dissenting voice, the roll call showing 121 delegates, representing 53 societies, voting in the affirmative; 8 delegates representing 5 societies present but not voting; and none voting in the negative.

Chairman Townley announced that the Joint Conference Committee had endeavored in all possible ways to facilitate the work of the Organizing Conference so as to conserve time and with this in view he offered the following suggestions for Committees:

Committee on Constitution and By-Laws, to deal with the form of the proposed organization embodied in a constitution and bylaws, to which the Joint Conference Committee had given consideration and would offer for the guidance of the proposed committee, the results of its deliberations.

Committee on Resolutions to which could be referred important resolutions of the Conference, for consideration and report.

Committee on Program to consider the program arranged by the Joint Conference Committee and make any changes or modifications which in its judgment were necessary.

The addresses by Arthur P. Davis, Philip N. Moore and Leroy K. Sherman, scheduled for the morning session were presented at the afternoon session and the remainder of the program was completed.

The report of the Committee on Program was presented by its Chairman, Robert H. Fernald. This report approved the program as prepared by the Joint Conference Committee, with the exception that it was recommended the report of the Committee on Resolutions, scheduled for presentation at the Friday evening session, be made an order of business for 4:30 p. m. at the Friday afternoon session. The report was unanimously adopted.

The evening session was held at the New Willard Hotel, and interesting addresses were presented by Homer L. Ferguson, James H. McGraw, and George Otis Smith. These were followed by a smoker under the auspices of the Washington Society of Engineers and its affiliated organizations.

The report of the Committee on Constitution and By-laws was presented by its Chairman, Richard L. Humphrey, at the Friday morning session. The Committee reported on the resolutions that had been referred to it by the Conference, and its recommendations were approved by the Conference.

Mimeographed copies of the proposed Constitution were distributed; it was then read by the Chairman and considered paragraph by paragraph; some minor modifications were made and the Constitution unanimously adopted. The vote showed 90 delegates, representing 57 societies, present and voting in the affirmative; none voting in the negative: 27 delegates refraining from voting because of instructions from the Societies they represented, limiting their power.

Mr. F. M. Feiker speaking for fourteen representatives of technical papers in attendance at the Conference, was recognized by Chairman Townley and stated that these technical press representatives were extremely interested in the proposed organization and wanted to aid the movement through publicity and in other ways and with the view of bringing about a close affiliation between the representatives of the press and the new organization, he offered an amendment to the Constitution providing for publicity which after some discussion was referred to the Committee on Constitution and By-laws.

At the afternoon session the Committee on Constitution and By-Laws reported on the resolution offered by Mr. Feiker at

the morning session, and its recommendation that the following be inserted in the Constitution, as Article X was agreed to.

"This organization stands for the principle of publicity and open meetings under such regulations as may be provided in the By-Laws."

The Committee further recommended that there be inserted in the By-Laws, the following:

Chap. IV. Publicity

Sec. 1. The privilege of attendance at all meetings of the American Engineering Council, of the Executive Board, and of Committees, when not in executive session, should be extended to any proper person, but this privilege does not extend the right to speak or vote. Any proper person shall have the right to inspect and make true copies of the official records of all meetings of the Council, the Executive Board, and the Committees.

Sec. 2. The Publication Committee may employ a Publicity Secretary whose duty, under the direction of the Executive Board, shall be to prepare and supply to the engineering, technical and general press, information concerning the Federated American Engineering Societies, or the engineering world, and to cooperate with the editors of engineering and technical publications in disseminating information in regard to the organization and its activities. The Publication Committee may appoint a cooperating board of engineering editors to counsel and assist in any or all of its activities.

Mimeographed copies of the By-Laws were distributed. The Chairman then read the By-Laws as thus amended, which were discussed and unanimously adopted without a roll call.

The Constitution and By-Laws as amended were referred back to the Committee for editing and will be printed and distributed at the earliest possible moment.

The Chairman of the Committee on Constitution and By-Laws stated it was the opinion of the Committee that there should be an ad interim Committee to carry on the work during the period following the adjournment of the Organizing Conference and the convening of the American Engineering Council and offered the following resolution, which was unanimously adopted:

That it is the sense of this Committee that the Joint Conference Committee should be entrusted with making provision for putting the conclusions of this Conference of Engineers into effect, and that we recommend to the Conference that Engineering Council be requested to carry on its work until the new organization has been established by all proper means to further the program of the new organization, and that the Conference recommends to the contributing societies that they continue supplying the funds required by Engineering Council until its work is taken over by the new organization.

Mr. O. J. Sterrett, delegate from the Detroit Engineering Society, stated that the Society that he represented had voted to join the new organization at its last meeting.

The delegates of the American Society of Mechanical Engineers, through their Chairman, L. P. Alford, stated that they had been sent to the Conference with power to act for their organization and announced that that Society pledged its membership in the new federation. Mr. Calvert Townley, President of the American Institute of Electrical Engineers, stated that he could predict with reasonable certainty that the Institute would also at an early date pledge its membership in the new organization.

The delegates of a number of other societies stated that while the matter would have to be referred back to the organizations which they represented for final action, it was their opinion that this action would be favorable.

The report of the Committee on Resolutions was presented by George G. Anderson and was unanimously adopted:

Major Bond, representing the Society of American Military Engineers, presented a brief outline of the work of this new organization and made an appeal to all American Engineers to become identified with the organization and thus aid by doing their bit toward keeping America prepared for future emergencies.

The afternoon session concluded with the adoption of resolutions of appreciation of the work done, in organizing the Federated American Engineering Societies by the Joint Conference Committee and by the Committee on Constitution and By-Laws which were extended by the Chairman Townley to Richard L. Humphrey the Chairman of both these Committees, and by Chairman Calvert Townley who presided over all sessions of the Conference.

The Conference finally adjourned Friday evening following addresses by Samuel M. Vauclain, President of the Baldwin Locomotive Works, Robert S. Woodward, President of the Carnegie Institution, James R. Angell, Chairman of the National Research Council, and an informal reception and smoker at which the delegates and guests of the Organizing Conference were the guests of the Washington Society of Engineers and the Affiliated Organizations.

The meeting of the Organizing Conference was thoroughly representative. National, Local, State and Regional Engineering Organizations, from Maine to California and from the Gulf to the Lakes had delegates in attendance. The gathering is unparalleled in the history of the engineering and allied technical societies of this country and marks a forward step in the history of these professions. The Conference had two distinct characteristics, the business sessions which moved smoothly and harmoniously, voicing the unanimous desire of the engineering societies of this country for a comprehensive organization as planned by the Joint Conference Committee; and the sessions at which addresses of an inspirational character were presented. The deliberations were characterized by great harmony and a form of organization, including Constitution and By-Laws, was adopted without a dissenting vote; if the attitude of the delegates in attendance reflects the spirit of the organizations they represent, it is evident there is a wide-spread and unanimous desire for some form of comprehensive organization that will represent the solidarity of these professions.

The Joint Conference Committee will send to various organizations, reports of proceedings in the Organizing Conference, including the inspirational addresses referred to and the Constitution and By-Laws that have been adopted. It will also send at a later date formal invitations to become members of the Federated American Engineering Societies and to send delegates to the American Engineering Council which is expected to hold its first meeting either during the latter part of October or the first part of November; the call for this meeting announcing the time and place will be sent in due course by the Joint Conference Committee.

The Joint Conference Committee feels that it reflects the unanimous judgment of the representative body of Engineers that attended the Organizing Conference in Washington when it states that at this historic meeting action of the greatest importance to the future of the engineering and allied technical professions was taken in the formation of a comprehensive organization that will represent these professions in a service dedicated to the city, state and nation.

The Joint Conference Committee strongly urges the engineering and allied technical societies of this country to take immediate action in the matter of becoming members, to appoint at an early date delegates to participate in the first meeting of the American Engineering Council and in all ways do their bit in making eminently successful the new organization which shall speak for these professions in all matters affecting the public welfare, where technical knowledge and engineering experience are involved, and on other matters of common concern to the public and to these professions.

The constitution, in accordance with the instructions of the conference, is now in the hands of an editing committee, and will be published later in its complete and finished form. The main features of the Constitution are as follows:

Membership. Membership is to consist of national, local, state and regional engineering and allied technical organizations and affiliations, classified as follows:

(1) National engineering and allied technical organizations.

(2) Local, state, or regional engineering or allied technical organizations other than local associations, sections, branches or chapters of national organizations.

(3) Affiliations consisting of local sections of national organizations, local engineering societies or clubs and local engineers.

Management. The management of the new organization is to be vested in a body known as the American Engineering Council and its Executive Board. This Council is to consist of representatives of member societies each of which shall be entitled to one representative for a membership of from 1 to 1000, and one additional representative for each additional thousand members or a major fraction thereof. This Council is to hold an annual meeting. The elected officers of the Council will be a president, to hold office for two years, four vice-presidents to hold office for two years, two to be elected each year, and a treasurer to hold office for one year. An Executive Board is also provided, to consist of thirty members of the Council, and this Board is to conduct the business of the new organization under the direction of the Council. The six officers selected by the Council are to be members of this Executive Board and the balance of twenty-four shall be selected by the National Societies and local, state and regional organizations according to districts. The president and secretary ofthe Council shall be, respectively, the chairman and secretary of the Executive Board.

Funds. The funds for the use of the new organization are to be obtained in the following manner: Each national member society represented on the Council is to contribute annually $1 50 per member. Each local, state or regional organization represented is to contribute annually $1 per member.

Local Affiliations and State Councils. The Council is empowered to encourage the formation of local affiliations to consider matters of purely local public welfare with which the engineering profession is concerned. It is also authorized to create state councils consisting of representatives of the local affiliations within the state. These councils are also for the purpose of considering matters of public welfare as associated more particularly with state matters.

The delegates appointed to attend the meeting on behalf of the A. I. E. E. were as follows: H. W. Buck (*chairman*), New York City; C. A. Adams, New York City; A. W. Berresford, Milwaukee, Wis.; John H. Finney, Washington, D. C.; James H. McGraw, New York City; L. F. Morehouse, New York City; E. W. Rice, Schenectady, N. Y.; L. T. Robinson, Schenectady, N. Y.; Samuel Sheldon, Brooklyn, N. Y.; C. E. Skinner, East Pittsburgh, Pa.; Calvert Townley, New York City; R. H. Dalgleish (*alternate*), Washington, D. C.; C. F. Lacombe, (*alternate*), Babylon, L. I.

FEDERATED AMERICAN ENGINEERING SOCIETIES ENDORSED BY ENGINEERING COUNCIL

Engineering Council has in numerous ways expedited the creation of a comprehensive, representative body to perform for the engineers of America in a larger fashion, such functions as Council has performed for the past three years. At its meeting in October, 1919, Council endorsed the general plan for a national engineering council, as outlined by the Joint Conference Committee of the Founder Societies. January 23, 1920, it assembled in joint meeting in Engineering Societies Building, the governing bodies of all its member societies and United Engineering Society, at which meeting the plan was given strong impetus. Through its Washington office, and otherwise, Council aided the Organizing Conference of Technical Societies, held June 3 and 4, in Washington.

At its regular meeting June 17, 1920, after hearing a report on the Organizing Conference, Engineering Council took the following actions:

VOTED: that Engineering Council heartily endorse the plan of organization of the Federated American Engineering Societies and the American Engineering Council, adopted by the Organizing Conference of technical societies in Washington June 3 and 4, and authorize its Executive Committee to proffer and perform on the part of Council such assistance as may be practicable in completing the work of the Organizing Conference and of the Joint Conference Committee of the Founder Societies in establishing the American Engineering Council.

VOTED: that Engineering Council authorize its Executive Committee to deal with any question of cooperation with the Joint Conference Committee of the Founder Societies, relating to the permanent organization of the Federated American Engineering Societies, which may come up during the summer.

VOTED: that the Secretary be instructed to invite to future meetings of Engineering Council delegates of the societies participating in the Organizing Conference in Washington, June 3 and 4, and editors of technical journals who may be interested.

JOINT MEETING OF FOUNDER SOCIETIES

A special joint meeting of the founder societies was held in the Engineering Societies Building on May 26, 1920, having for its subject the value to the Engineering Profession of a liaison between the Engineering Societies of Russia and of America, to further cooperation for the benefit of the engineers of both countries. Mr. Walter N. Polakov, Member, American Society of Mechanical Engineers, presided, and the speakers were Mr. N. A. Stephanoff, President, Russian Society in America, and Mr. W. F. Dickson, Director, Russian Singer Company. An illustrated lecture upon the resources of Russia was given by Dr. J. M. Goldstein, Professor of Economics, Moscow University.

Mr. Stephanoff's address was on the subject of the Russian engineer as a personality. From the three viewpoints of training, social situation, and psychological characteristics, he discussed briefly his fellow engineers. A few of the high points he touched upon follow:

In Russia, engineers were divided into two classes: that of the engineers who had been graduated from the high technical schools and received their diplomas, which can be compared to the Massachusetts Institute of Technology; these were termed "Graduate Engineers." The second class composed the practical engineers from special technical colleges.

Every specialty of engineers had its own societies, grouping all its members, as the Government of the old Regime was strongly opposed to any scheme of one large union, which would have united all the engineers of Russia. However, within two months of that Government's overthrow, one All-Russian Engineers Union was formed, which admitted in its ranks, not only the graduate engineers but also the practical, regardless of political opinion as this Association, which counted about 60,000 members, was a purely professional organization.

My second point was the social situation of the Russian engineer. Sixty per cent of Russian engineers made their careers in the government administration, which provided them becoming uniforms and not a few glittering decorations. They were always deprived of their initiative by the government. About 10 per cent, let us say, allowed their training to become unproductive, and the remaining 30 per cent found their way into industry where they had to compete with foreign, and especially German, engineers, and it is only during the fifteen years which preceded the war that they really began to come into their own and occupy the first place in their own country.

I will now pass on to the third point; that of the psychological characteristics of the Russian engineer:

First come his disinterestedness and absence of selfish aims in his work. I can best illustrate this by mentioning that during my 22 years of experience in Russia, I never heard of one industrial engineer having made money.

The Russian engineer's special ability for construction had, as you know, attracted the attention to the famous Professor Bach, whose motto was: "Less Invention, More Construction." In addition shall I term as a peculiarity the Russian engineer's belief that, independently from any political point of view, the first place belongs to men, the second to animals, and the third to machines, contrary to the general practise ascribing the first place to machines, the second to animals, and oftentimes no place at all for men?

Mr. Dickson spoke on Russian achievements ine ngineering among which he included the following:

In the field of bridge building some very fine work has been accomplished. The suspension bridge across the Dnieper at Kiev, the bridges over the Volga at Syzran and Yaroslavl, the Palace Bridge over the Neva at Petrograd—all rank high among similar structures in this and other countries.

The great Siberian Railway stretching from the Gulf of Fin-

land to the Pacific Ocean and linking together Petrograd and Vladivostok, cities almost exactly five thousand miles apart, can be compared very favorably with our own transcontinental lines. The skill displayed by the Russian engineers in spanning the wide Siberian rivers and in piercing, as I remember it, forty-two tunnels through the rocky cliffs bordering the southern shore of Lake Baikal, situated about halfway across Siberia, is something engineers of any nationality might be proud of.

In a museum at Nijni-Tagil there is, or was, preserved a steam engine built by a mechanic named Polzunoff for his own use for mining purposes in the Ural Mountains, which is credibly stated to have antedated, by a few years, James Watt's first steam engine (1765). It was in use for over a hundred years.

In the realms of electricity Russia has not lagged behind. Those of us who are still only middle aged will remember the invention of the Russian engineer Yablokoff of the arc light. I am not prepared to say that his was the first application of the arc for lighting purposes, but if it was not actually the first, it was amongst the earliest and most practical and was an independent invention. Lodegin produced an incandescent lamp at a time when electricity as a means of lighting was just beginning to be thought of. Dolevo-Dobrovokski developed the theory and practical application of the three-phase current.

The Russian Professor Popoff invented wireless telegraphy simultaneously with Marconi and the latter, I understand, freely acknowledges this.

In aeronautics Russia has been well to the fore. Sikorski designed and built in 1912 what I believe was the first aeroplane to carry a dozen or more persons.

WATER POWER LEGISLATION

The long-pending water power development bill received final action by Congress when the Senate approved the conference report by a vote of 45 to 21.

When the bill was sent to the President for signature it had to be referred to the Secretary of the Interior, the Secretary of Agriculture and the Secretary of War because it involved parts of bureaus and offices coming under their jurisdiction. The Secretary of the Interior recommended to the President that this bill be held up because of the effect which, it had been reported to him, would be had on the National parks. When the Secretary was apprised of the facts in the case however he withdrew his objections to the legislation, but it was then too late for the President to sign the bill because Congress adjourned that afternoon.

A subsequent ruling from the Attorney General's Office declared that under existing conditions the President could still sign the bill within ten days from the time it was received from Congress, and that the bill would become law by such action. This time limit expired on June 11th at midnight, and several days after this it was announced that the President had signed the bill within the time limit specified thus making it a law.

POLITICAL PARTY ENDORSES DEPARTMENT OF PUBLIC WORKS IN PLATFORM

One of the planks in the platform of the Republican Party at Chicago read as:

Reorganization of Federal Departments and Bureaus. "We advocate a thorough investigation of the present organization of the Federal departments and bureaus with a view to securing consolidation, a more businesslike distribution of functions, the elimination of duplication, delays and overlapping of work and the establishment of an up-to-date and efficient administrative organization".

This was initiated and brought about by the National Public Works Dept. Assn. It is understood in Washington that the Smoot-Reavis bill proposing a general reorganization of all departments along the lines suggested by the Engineers for the Department of Public Works carries the provision that the first department to be so reorganized will be the Department of the Interior and its conversion to a Department of Public Works.

IMPORTANT CONFERENCE ON HUMAN RELATIONS IN INDUSTRY

Under the Auspices of a Committee of Prominent Leaders of Industry Cooperating with the Y. M. C. A.

There will be held this year at Silver Bay, Lake George, New York, August 27th to 29th, a conference on "Human Relations in Industry." Over six hundred representatives of industry are expected to attend, including some of the most prominent industrial leaders. Among the speakers who have already accepted are Mr. Allen T. Burns, Americanization Study of the Carnegie Foundation for the Advancement of Teaching; Mr. F. J. Kingsbury, President, Bridgeport Brass Company; Mr. Clarence H. Howard, President, Commonwealth Steel Company; Mr. C. J. Hicks, Assistant to the President, Standard Oil Company; Mr. R. B. Wolf, Consulting Engineer; Mr. S. J. Carpenter, Lumber Manufacturer; Mr. L. P. Alford, Editor, Industrial Management; and Mr. Timothy Healy, International Brotherhood of Stationary Firemen.

A similar conference held at Silver Bay last year, attended by five hundred prominent industrial leaders and others, created a demand for a larger conference this year. The greatest problems of the day are industrial. The most important factor in industry is the human factor. Men dealing with the human factor want to get together, exchange experiences, and discuss these matters with experts in the field. The conference at Silver Bay affords the ideal opportunity. Members of the A. I. E. E. who would like to attend should reserve accommodations through Mr. Fred. H. Rindge, Jr., Secretary, Industrial Service Movement of International Y. M. C. A., 347 Madison Avenue, New York City.

FALL MEETING OF A. I. M. E.

The American Institute of Mining and Metallurgical Engineers will hold its fall meeting in the Lake Superior, Copper and Iron districts, August 20 to September 3, 1920. Houghton will be the first general assemblying place, and from there a trip will be made by special trains to Duluth, one train by way of Ishpeming, another by Vulcan. From Duluth the guests may either return to Chicago by special train, or go to Buffalo by steamship.

Technical sessions have been provided for at various stops, also social entertainments. Those who make the trip will have a chance to see many interesting developments in mining engineering, such as a new hoisting plant, from a depth of 12,500 feet, which will be in operation at the time of the visit in Houghton. Members are requested to make early reservations for themselves and their guests, as accomodations are limited.

ILLUMINATING ENGINEERING SOCIETY ELECTS OFFICERS

The election of the following officers of the Council of the Illuminating Engineering Society for the fiscal year 1920-1921, was confirmed by the Council on June 11th, 1920. These men were elected to fill the offices made vacant by expiration of terms: President: General George H. Harries; Vice-Presidents: H. F. Wallace, Dr. Geo. S. Crampton, J. J. Kirk; General Secretary: Clarence L. Law; Treasurer: L. B. Marks: Directors: Adolph Hertz, Walton Forstall, Frank S. Price.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

CLASSIFICATION AND COMPENSATION OF ENGINEERS

In reserving its efforts to advance the material as well as the professional interests of the members of the engineering profession, the Committee on Classification and Compensation of Engineers, of Engineering Council desires the benefit of the views of individual engineers as to the suitability of the scale of compensation and the employment policy suggested in their report which was published in the February 1920 issue of the JOURNAL of the Institute. Information of this sort will be of substantial assistance in enabling the Committee to complete its investigation and it is intended to make it available to any group of engineers for use in discussing these matters with those who have responsibility for fixing compensation. Members of the Institute and other interested engineers are urged to communicate any information which they may have or to express their views to Arthur S. Tuttle, Chairman, 1347 Municipal Building, New York.

EXTRACTS FROM REPORT OF NATIONAL SERVICE DEPARTMENT

June 17, 1920

Since the last meeting of Engineering Council many events of interest have taken place in connection with the work of the National Service Department and it is believed that the interval has been productive of more useful results to the engineering profession than in any similar period since the establishment of the Washington office. In many instances the efforts of the Department with respect to legislation, appointments, etc. have been apparently non-productive, yet this statement is true with respect to the work of every other organization in Washington, not excluding Congress itself. An impartial survey of the situation demonstrates that we have experienced a smaller percentage of failures than almost any other public body interested in National affairs. It is to be remembered that failure in a tangible instance does not mean lack of progress. In the matter of securing the appointment of engineers to engineering positions, for example, every time we fail we become stronger for the next attempt. Overlying all is the fact that we are still new in the field. Official confidence is something that is secured slowly, and the engineers cannot expect after decades of non-participation to jump into the arena and achieve success over night.

Requests for Assistance and Information. During the past seven weeks requests for assistance and information from the engineering profession have numbered 62.

Among the special services rendered and not included in this number are: (a) a full report on the status of compulsory military training, for the Colorado Society of Engineers; (b) efforts to secure the appointment of a representative from the American Society of Mechanical Engineers to the Council of the Petroleum Research Institute; (c) the effect of the proceedings of the Buenos Aires trade mark convention on copyrights in this country, for the American Society of Mechanical Engineers; (d) the accredited status of the so-called Swiss Economic Tours, for the American Society of Mechanical Engineers; (e) an investigation of the substitutes devised and used by Germany during the war period, at the request of the American Society of Mechanical Engineers. It is an interesting fact that the American Society of Mechanical Engineers makes more use of the Washington office of Engineering Council than do all of the other member societies combined.

Appointment of an Engineer to the International Joint Commission. Shortly after the death of Governor Glynn, a member of the International Joint Commission, Council's request for the appointment of an engineer in his place was presented at the White House, accompanied by a list of engineers who were regarded as qualified for service on that commission. This effort was supplemented by representations made to members of Congress who are supposed to be interested or influential in the matter, and also by several engineering organizations in the State of Minnesota, especially in advocacy of the appointment of Mr. Shenehon. Our last advice is that the President had received and taken note of the several recommendations and had determined upon the appointment, but we have so far been unable to ascertain the name of the appointee.

Appointment of Engineer to Interstate Commerce Commission. As the representatives on Council are probably aware our efforts to secure the appointment of an engineer to the Interstate Commerce Commission failed. The President appointed three representatives but the Senate refused to confirm the appointments and since the adjournment of congress these three men have been given recess appointments.

Advisory Board to Post Office Commission. Efforts to secure the appointment of one or more engineers on the Advisory Board attached to the Post Office Commission for the study of mail transportation systems in cities have apparently failed.

Advisory Council to the U. S. Board of Surveys and Maps. The Washington representative has completed his duties in connection with the organization of this council, and the future activities of Council will probably be guided by the necessities as they appear from time to time.

Convention Assistance. Among the time-consuming the laborious duties carried on by Mr. Oliphant of the Washington office are the work for the Joint Conference Committee in caring for the local arrangements of the organizing conference of engineering societies, which was held in Washington, and similar work for the Chairman of the Convention Committee of the American Institute of Electrical Engineers in connection with the forthcoming White Sulphur Springs convention.

Amendment to the War Minerals Relief Act. At the last meeting of Council your representative was authorized to proceed adversely to the legislation amending the present War Minerals Relief Act, and is glad to report that although the bill was slipped through the Senate, action in the House has apparently been blocked, and even the bill which passed the Senate contains errors which will make its reconsideration necessary by that body. As such reconsideration can be secured with difficulty, except by unanimous consent, and as unanimous consent is apparently impossible to secure, it is believed that this bill has been effectively killed for the present at any rate.

Taxation of Personal Service Corporations. It is believed that Council may render service to the entire profession by calling the attention of the engineering organizations to pending legislation on the taxation of personal service corporations. The bill is H. R. 14197 and has been favorably reported from the Committee on Ways and Means and is now on the

union calendar of the House of Representatives. "A personal service corporation, as defined in the revenue law of 1918, means a corporation whose income is derived from a profession or business (a) which consists principally of rendering personal service; (b) the earnings of which are to be ascribed primarily to the activities of the principal owners or stockholders; and (c) in which the employment of capital is not necessary or is only incidental * * * * * *."

Obviously, this includes engineering corporations, of which there are a large number in the United States, and the prosperity of which affects the professional welfare of all members of the profession whether in the employer or employee class.

The provisions of the act of 1918 taxed these corporations practically the same as partnerships, but the decision of the Supreme Court, while not specifically mentioning such corporations, has raised a question as to whether this portion of the act of 1918 is not invalid. The effort of the Committee on Ways and Means to pass legislation covering these doubtful points was inspired by a letter of the Secretary of the Treasury dated March 17, 1920 recommending amendatory legislation to make certain that the decision of the Supreme Court relative to stock dividends does not exempt from income and profits taxation personal service corporations and their stockholders. Time will not be taken here to analyse the facts and conditions and proposed legislation. It is recommended, however, that the matter be referred to an attorney-at-law for thorough analysis and that a small committee consisting of engineering stockholders in such corporations who are members of one or all of the constitutent societies of Engineering Council be requested to prepare a statement on the subject for circularization among the engineers of the country, and that when the proper time arrives steps be taken to present to Congress the opinions which are finally evolved by this committee. It is very clear that unless Congress is made aware of the peculiar conditions and circumstances that surround the conduct of professional engineering corporations the bill as finally enacted may contain provisions wantonly detrimental not only to the corporations themselves but to all engineers who directly or indirectly are affected by the progress or poverty of these corporations.

Nation Plans. The writer desires to invite Council's attention to a project which involves a long forward look—something which cannot be accomplished within a short time but which the writer believes to be worthy of a place on the constructive program of the engineers of the country. The subject is nation planning, the essential feature of which is the extension to national scope of the principles and ideals underlying what we know as city planning, that is, the efficient arrangement and direction of the public and private utilities of the Nation so that they will contribute to the maximum extent to the social, industrial and economic weal. The fact is becoming more and more apparent that the cities are after all merely the foci through which the economics of the Nation are made manifest, and city planning is but the first economic step in the improvement of our economic status.

This matter of nation plans has been visualized by Mr. Cyrus Kehr of Knoxville, Tenn., who has organized the so-called "Joint Board on Nation Planning," of which he is Chairman.

Mr. Kehr is a visionary man whose dreams tend to converge toward practicalities. He has completed the manuscript of a book on the subject of nation plans, which the writer has read with much interest. Of course the subject is too big for any one man and the great merit of Mr. Kehr's work lies in its ideals and generalities. He clearly describes a field full of logic and promise, while his discussion of details is valuable if for no other reason than to reveal the complexity of the subject and to show the need for many wise guiding hands. The whole subject is so attractive that it will, (if indeed it not already has,) stir the imagination of the chronic reformers who are constantly looking for new Elysian fields. If this movement is not steered wisely it will result in untold misfortune, disarrangement of values, disruption of credit and industrial chaos. The country is now in a condition to go to extremes on everything that is new so long as it is sufficiently revolutionary. For that reason, if for no other, it appears to the writer wise that this movement be guided by men of stability, while on the other hand it is believed that it contains so vast a field of merit that it is not only worth while but also highly desirable.

The matter is in large degree an engineering concern and it is thought appropriate for the consideration of Engineering Council. It is suggested that Engineering Council act for the present as a committee of the whole on this subject and that each member review the proposal between the present and the next meeting of Council, the idea being to take positive or negative action at the October meeting.

COMPARISON OF REPORT OF CONGRESSIONAL JOINT COMMISSION WITH REPORT OF COUNCIL COMMITTEE ON RECLASSIFICATION OF SALARIES

On March 12, 1920, the Congressional Joint Commission on Reclassification of Salaries presented its report to Congress. Ever since this report was made public, discussion concerning it has been rife, and naturally much misunderstanding about the recommendations regarding salary schedules and employment policies has gained currency. In an endeavor to clear up these misunderstandings and in order to present an analysis of the Commission's report, the Committee on Classification and Compensation of Engineers presents the accompanying table "Comparison of Report of the Congressional Joint Commission on Reclassification of Salaries with the December 1919 Report of Council's Committee."

The essential features of the Joint Commission's report are incorporated in the table which shows the salary range for the various grades of service as compared with that suggested by Engineering Council. The table also shows how the average salary as proposed by the Joint Commission, compares with the average salary received by employees in 16 engineering bureaus in civil establishments of the Federal Government on July 1, 1919.

There have been certain increases since that date, particularly in positions carried on lump sum appropriations. It is probable, therefore, that averages at the present time would be slightly higher than those shown in Column 14, particularly in the lower grades.

The research staff of the Commission made estimates of the average salaries in the different classes for the Engineering service which are somewhat different from the figures of Column 14. They are slightly higher in the lower grades and slightly lower in the higher grades. These differences are brought about as follows: The Commission's averages are for the Washington service only. The averages in Column 14 include both the Washington and the field services. The Commission's figures included salaries paid in civilian positions in the War and Navy Departments. The Navy Department schedule is considerably higher than that of the civil bureaus and therefore the Commission's averages would be somewhat higher on this account alone. Finally, the averages will vary according to the classification of positions. It is believed that the Commission classified positions more liberally than Engineering Council's Committee. The Commission probably included more positions in the higher grades than did Council's Committee, with the result that the averages for these grades are lower in the Commission's than in Council's calculations.

Since the Commission in any comparison of proposed with existing salary scales will use somewhat different data, it is evident that the averages will not be identical. There appears no doubt, however, that in the lower two grades the averages proposed are less than the averages now paid with the bonus, but how much less will depend upon what positions are classed within these grades and what date is taken for determining the averages.

In the Professional Group, the Joint Commission recommends the same educational and experience standards for grades 5, 4, and 3 as Engineering Council, but it recommends 4 years "in the direction or performance of important engineering works for grade 2, and 8 years for grade 1, against Engineering Council" recommendation of 3 years, and 5 years, respectively. The Joint Commission provides for a minimum increase in salary from $1800 for grade 5 to $4140 for grade 2; *i.e.*, $2340, or 130 per cent in a minimum of eight years. Engineering Council provides for a minimum increase for the same grades and number of years from $1620 to $5940; *i.e.*, $4320 or 267 per cent more than double the rate of increase recommended by the Joint Commission.

TABLE SHOWING COMPARISON OF CLASSIFICATION AND COMPENSATION OF ENGINEERS

As Suggested by Engineering Council Committee and by Congressional Joint Commission and of Average Salary per Annum as Suggested by Congressional Joint Commission and Present Average Salary of Employees in 16 Engineering Bureaus in Civil Establishments of the Federal Service

Grade	Engineering Council: Title	Educational Equivalent	Minimum Experience in Years	Annual Salary Range: Minimum	Maximum	Estimated Average
1	2	3	4	5	6	7
8	a. Junior Aid, Office b. Junior Aid, Field	High School	0	1080	1560	1240
7	a. Aid, Office b. Aid, Field	"	2	1680	2400	1920
6	a. Senior Aid, Office b. Senior Aid, Field	"	5	2520	3240	2760
5	Junior Assistant Engineer	Degree	0	1620	2580	1940
4	Assistant Engineer	"	2	2700	4140	3180
3	Senior Assistant Engineer	"	5, 1*	4320	5760	4800
2	Engineer	"	8, 3*	5940	....	....
1	Chief Engineer	"	12, 5*	8100	....	....

Grade	Congressional Joint Commission: Title	Educational Equivalent	Minimum Experience in Years	Annual Salary Range: Minimum	Maximum	Estimated Average	Present Average Yearly Salary (Note)	Average Per Cent Increase or Decrease (Note)
1	8	9	10	11	12	13	14	15
8	a. Copyist Draftsman b. Junior Engineering Aid	High School Common School	0	840	1260	980	1215	—19
7	a. Draftsman b. Aid	High School	2	1200	1800	1400	1533	— 9
6	No Corresponding Grade							
5	Junior Engineer	Degree	0	1800	2160	1920	1959	— 2
4	Assistant Engineer	"	2	2400	3000	2600	2402	+ 8
3	Associate Engineer	"	5, 1*	3240	3840	3440	3128	+10
2	Engineer	"	8, 4*	4140	5040	4440	3801	+17
1	a. Senior Engineer b. Commissioner, Director, Chief Engineer, Chief, Superintendent, etc.	"	12, 8* 8, —*	—	—	—	5867	—

NOTES

Columns 4 and 10. *Years in responsible charge of work.

Columns 7 and 13. Estimated average salary is the minimum plus ⅓ the difference between the minimum and the maximum. This relation was found to hold approximately for positions in the Federal Service and was assumed in the studies conducted in connection with the salary schedules of the Reclassification Commission.

Column 14. Present average yearly salary, including bonus, of employees in 16 bureaus in civil establishments of the Federal Government. The bonus is $240 for salaries of $2500 and under; for salaries above $2500, it is the amount, if any, necessary to make a total of $2740.

Column 15. Average percentage increase (+) or decrease(—) in pay per employee under schedule proposed by Congressional Joint Commission over present schedule if distribution of employees within each grade remains unchanged. The estimated increase in the salary roll which would be caused by putting the Commission's recommendations for all branches of the Civil Service into effect is, as estimated by the Commission, 8 to 10 per cent, probably 8.5 per cent.

AMERICAN ENGINEERING STANDARDS COMMITTEE

SPONSORS FOR SAFETY CODES SELECTED

Definite arrangements have been made for the formulation of a considerable number of safety codes under the auspices and rules of procedure of the American Engineering Standards Committee. The subjects of the codes for which arrangements have been completed, together with the organizations which have been designated by the Committee to act as sponsors, and who have accepted such responsibility are as follows:

Abrasive Wheels. The Grinding Wheel Manufacturers of the United States and Canada, and the International Association of Industrial Accident Boards and Commissions, joint sponsors.

Explosives. The Institute of Makers of Explosives, sponsor.

Foundries. The American Foundrymen's Association and the National Founders Association, joint sponsors.

Gas Safety Code. The U. S. Bureau of Standards and the American Gas Association, joint sponsors.

Head and Eye Protection. The U. S. Bureau of Standards, sponsor.

Paper and Pulp Mills. The National Safety Council, sponsor.

Power Presses. The National Safety Council, sponsor.

Pressure Vessels, Non-fired. The American Society of Mechanical Engineers.

Refrigeration, Mechanical. The American Society of Refrigerating Engineers, sponsor.

Woodworking Machinery. The International Association of Industrial Accident Boards and Commissions and the National Workmen's Compensation Service Bureau, joint sponsors.

A number of additional codes are under consideration. A large representative advisory committee of specialists, organized by the National Safety Council, the National Workmen's Compensation Service Bureau, and the Bureau of Standards, at the request of the Committee, to act as its advisor, is actively working on the question of what additional codes are most urgently required and what organizations are in the best position to undertake sponsorship for such codes.

AMERICAN SOCIETY FOR TESTING MATERIALS SUBMITS SPECIFICATIONS FOR APPROVAL AS AMERICAN STANDARDS

At a recent meeting of the American Engineering Standards Committee, five standard specifications were submitted by the American Society for Testing Materials for approval as "American Standards."

1. Standard Specifications for Drain Pipes
2. Standard Test for Toughness of Rock
3. Standard Test for Penetration of Bituminous Materials
4. Standard Method for Distillation of Bituminous Materials suitable for Road Treatment
5. Standard Method for Sampling Coal

All of these specifications are included in the *Proceedings* of the American Society for Testing Materials, or copies may be obtained from the office of the American Engineering Standards Committee at New York. These specifications were referred to a special sub-committee to make recommendations to the American Engineering Standards Committee for final action.

STANDARDIZATION OF BALL BEARINGS

At the request of the Swiss Standards Association, Baden, Switzerland, for cooperation in the work of standardization of ball bearings, the American Engineering Standards Committee requested the American Society of Mechanical Engineers and the Society of Automotive Engineers to act as Joint Sponsors for the project. These societies have accepted the responsibility and are now organizing a Sectional Committee for the work. The Sectional Committee will be thoroughly representative of all the interests involved and is the body which will be responsible for the detailed formulation of the standards.

FOREIGN STANDARDIZING BODIES VISITED BY SECRETARY OF THE AMERICAN ENGINEERING STANDARDS COMMITTEE

The American delegates who attended the meetings of the Advisory Technical Committees of the International Electrotechnical Commission, at Brussels, March 27th to April 1st, were accompanied by P. G. Agnew, Secretary of the American Engineering Standards Committee, who later visited the national standardizing bodies in Belgium, England, France and Holland.

The Association Belge de Standardisation was organized by the Central Industrial Committee of Belgium. While only recently organized, the Association is actively at work and has already carried out several important standardization projects.

The French Commission Permanente de Standardisation differs from other national standardizing bodies in that it is strictly an official organization, and supported wholly by government funds. It is a part of the Ministry of Commerce and Industry. The standards already adopted include the specifications for cement, tile, brick, also standards for electrical machinery, steel sections, and various elements of machine tools, such for example as tool rests, lathe carriages, keys, and keyways.

Most American engineers are more or less familiar with the British Engineering Standards Association and its work. It is the oldest and largest of the national organizations, having been founded in 1901 as the British Engineering Standards Committee. The work of the Association is playing a most important role in British industry. The standards now in effect cover an extensive range of engineering subjects.

The Main Committee for Standardization in the Netherlands was organized in 1916, by the Society for the Encouragement of Industry and the Royal Institute of Engineers. As in the case of Belgium, the relatively small size of the country, and the industrial and commercial position necessarily affect their standardization work. The form of publication is unique. Standards are issued as single sheets, perforated for binding in loose-leaf folders. The essential information is given in compact form, any necessary explanatory notes being given on the back of the sheet. The general style is that of a working drawing, and the idea is that they shall be issued directly to the draughtsman in the plant. The price is 15 Dutch cents ($0.06) per sheet. Their work is proceeding very actively. New sheets are being issued at the rate of about one per week. There are 16 on the staff of the central office.

The American Engineering Standards Committee is already in active cooperation with some of the other international bodies, the most important project being that of steel sections (with the British). There is an almost unlimited field for such work, and Dr. Agnew reports that he found a most cordial attitude and desire for cooperation on the part of all of the organizations which he visited.

There are similar national standardizing bodies in Canada, Germany, Sweden and Switzerland, while one is in process of organization in Italy.

NEW BODIES REPRESENTED

Five additional bodies have been admitted to representation on the Main Committee of the American Engineering Standards Committee. They are:

Electrical Manufacturers Council (Electric Power Club, Associated Manufacturers of Electrical Supplies, Electrical Manufacturers Club)

Fire Protection Group (National Fire Protection Association, National Board of Fire Underwriters, Associated Factory Mutual Fire Insurance Companies, Underwriters Laboratories)

National Electric Light Association

National Safety Council

Society of Automotive Engineers

These, with the five engineering societies who founded the Committee, (American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing Materials), and the three government departments, added later, (Commerce, Navy, and War), make a total of thirteen organizations having representation on the Main Committee.

The Constitution of the A. E. S. C. provides for representation of "groups of organizations." It is the policy of the Committee to encourage representation by groups in such a manner that a group shall represent substantially the entire field of a particular industry in order that it may "be of national scope." In the opinion of the Committee the group plan makes both for efficiency in standardization work and for effectiveness of representation. The groups are autonomous, such matters as the apportionment of representatives and the allotment of fees among the constituent bodies resting wholly with the group.

Two of the new bodies have already designated their representatives as follows:

Electrical Manufacturers Council: LeRoy Clark, A. H. Moore, C. E. Skinner.

National Safety Council: C. P. Tolman, Chairman. Manufacturing Committee; Albert W. Whitney, General Manager, National Workmen's Compensation Service Bureau; Sidney J. Williams, Secretary and Chief Engineer.

NATIONAL RESEARCH COUNCIL

The National Research Council has elected the following officers for the year beginning July 1, 1920: Chairman, H. A. Bumstead, professor of physics and director of the Sloane physical laboratory, Yale University; First Vice-Chairman, C. D. Walcott, president of the National Academy of Sciences and Secretary of the Smithsonian Institution; Second Vice-Chairman, Gano Dunn, president of the J. G. White Engineering Corporation, New York; Third Vice-Chairman, R. A. Millikan, professor of physics, University of Chicago; permanent secretary, Vernon Kellogg, professor of biology, Stanford University; Treasurer, F. L. Ransome, treasurer of the National Academy of Sciences.

The Council was organized in 1916 under the auspices of the National Academy of Sciences to mobilize the scientific resources of America for work on war problems, and reorganized in 1918 by an executive order of the President on a permanent peace-time basis. Although cooperating with various government scientific bureaus it is not controlled or supported by the government. It has recently received an endowment of $5,000,000 from the Carnegie Corporation, part of which is to be expended for the erection of a suitable building in Washington for the joint use of the Council and the National Academy of Sciences. Other gifts have been made to it for the carrying out of specific scientific researches under its direction.

ANNUAL MEETING OF JOSEPH A. HOLMES SAFETY ASSOCIATION

The annual meeting of the council of the Joseph A. Holmes Association was held on March 5, 1920, at Washington, D. C.

This association was established to perpetuate the memory of Dr. Holmes, the creator and first Director of the Bureau of Mines, whose activities led to the inauguration of a nation wide movement for the conservation of life and health among the mining and metallurgical workmen and to the introduction of greater safety in these industries. Diplomas and medals of honor are awarded to persons in these industries for deeds of heroism in rescue work and to persons who may devise or put in use appliances for greater safety.

After presentation of various reports and other routine business a discussion was entered into on the necessity for obtaining much larger funds to carry on the work of the association. It was agreed that among others the various miners' unions would undoubtedly prove valuable sources of revenue if the benefits of the Association's work were properly placed before them. Big mining men and operating companies were also suggested as a fruitful source of funds.

The Committee on Awards, Diplomas, and Medals submitted a report in which it was shown that 16 awards had been made during 1919, the delivery of the diplomas and medals to take place at various public functions. In making the awards for 1920 the records of the Bureau of Mines and the reports of State Mine Inspectors have been carefully canvassed to locate deserving persons. Seven are recommended and their names with a brief statement of circumstances of the acts performed are included. All awards to date are for a very high order of heroism involved in rescue work.

The Institute is cooperating in this meritorious work and is represented in the Association by John H. Finney, Washington, D. C.

ADDRESSES WANTED

A list of members whose mail has been returned by the Postal Authorities, is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Arthur J. Hall, 624 East End Ave., Pittsburgh Pa.

2.—Lincoln Nissley, 1213 Pioneer Bldg., St. Paul, Minn.

3.—Cyril H. Light, Office of Inspector of Engineering Material, U. S. N., 938 Edison Building, Chicago, Ill.

PERSONAL

Carl A. Baer, of Carl A. Baer & Co., Engineers, Land Title Building, Philadelphia, announces that the firm's business will now be conducted under the name of Baer, Cooke & Company, Engineers, Land Title Building.

W. Frank Sutherland, formerly editor of Power House, has severed his connection with the MacLean Publishing Company, Toronto and has accepted a position on the engineering staff of the Deloro Smelting and Refining Company, Deloro, Ont.

E. K. Bibb has resigned from the Westinghouse Electric & Mfg. Company to accept the position of Assistant Electrical Engineer of the Jeffery-Dewitt Insulator Company. Mr. Bibb will be in charge of the factory testing and inspection for this company.

John D. Ball has resigned the Deanship of the School of Engineering of Milwaukee and has accepted a position as manager of the Planning Department for Ed. Schuster & Company of Milwaukee. Mr. Ball is retaining his affiliations with the School as vice president for the present.

Edward J. Cheney, secretary of the Standards Committee of the Institute, formerly connected with the General Electric Company and recently Chief of the Division of Light, Heat and Power of the Public Service Commission, Second District, Albany, N. Y., opened an office on June 1 at 61 Broadway, New York, for a general engineering and consulting practise, with particular attention to public utility problems.

L. Lustig, formerly with the G. & W. Electric Specialty Co., Chicago, and with the Switchboard Engineering Departments of the Westinghouse Electric & Mfg. Co., East Pittsburgh, and the General Electric Co., Schenectady, has been appointed

during his visit to his native country as engineer in charge of the Switchboard Engineering Department of the Křižik-Chaudoir Electric Mfg. Co., Karlin-Prague, Czechoslovakia

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L. Earl Deane is leaving the American Enameled Magnet Wire Co., where he has served for more than six years in the capacity of traveling engineer and salesman, and will take up work under the Board of Foreign Missions of the Presbyterian Church. His assignment is to their work in French Cameroun, West Africa. About six months will be spent in France for language work after which he will proceed directly to West Africa.

H. L. Dawson, manager of the Chicago Office of the Cutler-Hammer Mfg. Co., which handles the business of nineteen states with sub-offices in Cincinnati and Detroit, has been removed from the Peoples Gas Bldg. to the company's own building on the new Michigan Boulevard link (323 No. Michigan Ave.). This new building makes available considerable extra storage space for the company, becoming necessary with their growth of business.

OBITUARY

Oliver B. Hodgson, lately connected with the Stone Franklin Company in the capacity of electrical engineer, died in New York on February 8, 1920, after a lingering illness. Mr. Hodgson was born in New York on November 20, 1887. He was graduated from Pratt Institute, Brooklyn, in 1908, and the following year entered the employ of the New York Central Railroad, specializing later in axle lighting apparatus. He left the New York Central in 1917 to become electrical engineer with the Stone Franklin Company, which position he held until September, 1919, when he resigned on account of poor health. Mr Hodgson joined the A. I. E. E. as Associate in 1910.

James R. Nelson, Superintendent of Power House, San Joaquin Light and Power Co., Springville, Cal., died March 29, 1920, following an operation. Mr. Nelson was born in Kansas in 1885. He went to California in 1910 and entered the employment of the San Joaquin Light and Power Corporation of Bakersfield as Superintendent of the Kern River Power House, and held that position until 1915 when he was transferred to Springville, Cal., where he was Superintendent of the Tule River Power House, remaining there until his death. He was an Associate of the A. I. E. E., and had joined also the N. E. L. A.

Charles Blizard, an Associate of the Institute since 1894, died on June 12, 1920, after a prolonged illness. Mr. Blizard had been in the electrical industry for about thirty years, first with the Franklin Accumulator Company, and then with the Electric Storage Battery Company, which he joined in 1893 as manager of the New York office. Later he became manager of sales for the same company, with headquarters in Philadelphia, and then third vice-president in charge of sales, holding this position until his death. He had also been one of the governors of the Associated Manufacturers of Electrical Supplies since its beginning and was chairman of the finance committee of that association for a number of years.

Edmund Gybbon Spilsbury, mining and metallurgical engineer of international reputation, died suddenly of heart failure May 28, 1920, in the New York Eye and Ear Infirmary, where the operation for cataract had been successfully performed upon his eyes a few days previous. He was President fo the American Institute of Mining and Metallurgical Engineers in 1896 and of the Engineers' Club of New York in 1916 and 1917. He was also a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, The Institution of Mining and Metallurgy of Great Britain, the Mining and Metallurgical Society of America, the American Electrochemical Society, and of the Rocky Mountain Club of New York. As the representative of one or another of the national engineering societies, he was a Trustee of United Engineering Society from 1916 until his death; a member of Engineering Societies Library Board from its organization in 1913 until 1920, being its Chairman from 1918 to January, 1920; and a member of the Engineering Foundation Board from 1916 until his death. He was also a member of the Division of Engineering of the National Research Council, of Washington and New York. In all these societies and boards, he was an active, useful member, serving on numerous committees and contributing freely of his time and ability.

Born in London, England, in 1845, he attended school in Liege, Belgium, whither he went at an early age. His technical education was gained at the University of Louvain, Belgium; he was graduated in 1862. After leaving the University, he had a practical course at Clausthal, Germany. He came to the United States in 1870. His practise as a consulting mining engineer and metallurgist took him into many parts of Europe, Africa, the United States, Mexico and South America. During the winter and early spring of 1920, he spent a number of weeks in Brazil on a mining project for clients in the United States and had returned to New York only a few weeks before his decease.

In 1864 he entered service of the Eschweiler Zinc Company, Stolberg, one of the largest miners and smelters of lead and zinc in the world, as Assistant Engineer; 1865 took charge of that company's mines and works on the Island of Sardinia; from Sardinia he went to the Atlas mountains, in Morocco. In 1867 he entered the service of McClean and Stilman of London, and had charge of the construction of the iron gates for the Surrey Commercial Docks; in 1868 he was designing engineer with J. Casper Harkort and had charge of most of the detail work of the Keulenberg Bridge in Holland and the Danube Bridge in Vienna, also the Rhine Bridge at Dusseldorf. In 1870 he was again with the Eschweiler Corphalic Company as Chief Engineer. In 1870 he was sent by the Austro-Belgian Metallurgical Company to investigate the resources of the United States in lead and zinc. After spending two years in this work, he resigned in order to practise in the United States, where he was the first to introduce the Harz system of ore-dressing for the zinc ores of Pennsylvania and New Jersey. During this period he was engaged in explorations also on the northern shore of Lake Superior and in Colorado, Montana, Utah and California. From 1873 to 1875 he was engaged as General Manager of the Bamford (Pa.) Smelting Works; in 1879 he designed and built the Lynchburg Blast Furnace and Iron Works; he was also Consulting Engineer for the Coleraine Coal and Iron Company, of Philadelphia. In 1883, he became General Manager of the Haile Gold Mine in South Carolina, and in 1887 engaged with Cooper, Hewitt and Company, of New York, and was Managing Director of the Trenton Iron Company, Trenton, New Jersey, from 1888 to 1897. While Manager of these works, he introduced as specialities of their business the Elliot locked wire rope and the Bleichert system of aerial tramways.

In 1893 he presided over the sessions of the Mining Division of the International Engineering Congress, of the World's Fair at Chicago.

He was the author of a number of important technical papers. In a lighter vein he also wrote entertainingly. To the Mining and Scientific Press in 1915, he contributed "Technical Reminiscences." This narrative recalls early interesting experiences and the notable progress in mining engineering during his half-century of active practise.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

INSTRUCTORS: All engineers willing to consider teaching positions are invited to register with Engineering Societies Employment Bureau. The Bureau has been called upon to fill more positions, varying in grade from laboratory assistant to heads of department, in various engineering and technical schools of this country, than it has been able to do from among the men now registered. Blanks for purpose of registration and information regarding the Bureau may be had by addressing W. V. Brown, Manager, 29 West 39th Street.

GRADUATE MECHANICAL AND ELECTRICAL ENGINEER, experience in car shop work. Competent to keep in first class condition of maintenance sub-surface-contact, electric, street railway cars, and to develop a repair shop for that work, selecting and placing the proper tools and take charge of such operations when effected. Location New York City. Z-1211.

INSTRUCTOR for technical school in electrical laboratory and class room work. Duties will include responsibility for an elementary electrical course, and assistance in a more advanced course. Must be engineering school graduate with few years practical experience. Previous teaching experience desirable. Apply by letter stating age, education and experience and enclose recent photograph if available. Location Brooklyn, New York. Z-1214.

ENGINEER for research and investigation on cable insulations. Must be able to conduct investigation on own initiative and report progress to company. Location Hastings, N. Y. Z-1272.

ELECTRICAL OR MECHANICAL ENGINEERS, technically trained, with selling experience on electrical or power plant installations to go to Columbia or Venezuela. Prefer men who have been through the General Electric Company's test. Age between 25 and 35. Z-1275.

INSTRUCTOR IN ELECTRICAL ENGINEERING. Duties beginning September 1st, in New England Engineering College, mainly instruction in electrical engineering Laboratory. Graduate of one or two years engineering experience desired. Z-1284.

INSTRUCTOR in Electric department school. Location Connecticut. Z-1331.

ELECTRICAL ENGINEER for research work on high-frequency current and particularly its application to plant life (electroculture). Must have thorough technical education and have had considerable experience in conducting research and in the practical application of the results therefrom. A knowledge of either chemistry, and allied subjects, or botany or of both, while not essential, is highly desirable. Although it involves his being absent from the United States for rather long periods at a time, this is an excellent opportunity for the man who can carry on the work, develop its practical application to industrial problems and later direct the research of others along similar lines. Z-1337.

ELECTRICAL ENGINEER to translate from French into English. German also desirable but not essential. Location New York State. Z-1352.

SUPERINTENDENT OF MINING property in Chile Technical graduate, preferably in Electrical or Mechanical. Executive and operating experience in electric railroading, steam turbine power plant, and open pit mining desirable. Only experienced men wanted. Knowledge of Spanish desirable, but not necessary. Good opporunity for right man. Give age, married or single, education, technical training technical and executive experience, salary expected, references and when available. Location Chile. Z-1355.

INSTRUCTOR IN ELECTRICAL ENGINEERING for 11 months work commencing September 1st. Candidates should be graduates with an Electrical Engineering degree and should have had some experience either in practical work or in teaching. Location Ohio. Z-1359.

GRADUATE MECHANICAL ENGINEER, with electrical and shop experience for large textile mill. The position will be that of Mechanical Superintendent and will embrace direct supervision of machine, carpenter, pipe, blacksmith, tinsmith shops, etc. The work will require a man with executive qualifications and a large amount of tact. State training, age, references, salary and other details necessary for reaching quick decision. Location Rhode Island. Z-1389.

GRADUATE ELECTRICAL ENGINEERS under thirty years of age, for investigating problems of inductive interference between power and communication circuits and for designing remedial measures in the Rocky Mountain region. Positions are open for men to take the lead in this work and for assistants. Preference given to those having experience in radio, telegraph and telephone work. Apply stating salary required. Z-1410.

SUPERINTENDENT familiar with small generator construction for department employing about 60 men engaged in manufacturing engines, switchboards, and generators for farm lighting plants. One man as general factory superintendent, who has a production knowledge in the items mentioned and understands the importance of keeping in contact with the working men in actual production operations. Location Wisconsin. Z-1411.

WORKING FOREMAN who knows how to wind armatures and has a general knowledge of small generator manufacture of about 1 kw. capacity. Location Wisconsin. Z-1412.

INSTRUCTOR IN MATHEMATICAL DEPARTMENT, young man. Principal work will be to give an elementary course in calculus to engineering students. Location New York State. Z-1439.

EXAMINATION TO FILL VACANCIES IN THE COMMISSIONED GRADE OF ASSISTANT CIVIL ENGINEER, CORPS OF CIVIL ENGINEERS, U. S. NAVY

Applications are being received at the Bureau of Yards and Docks, Navy Department, Washington, D. C., to fill 30 vacancies, more or less, in the commissioned grade of Assistant Civil Engineer, U. S. Navy, with the rank of Lieutenant (junior grade) The pay and allowances at entrance are approximately $3,200 per annum, with increases up to $9,600, depending upon length of service and promotions.

The candidate must be an American citizen, between the ages of 21 and 34 years on August 1, 1920; must have received a degree in engineering from a college or university of recognized standing; must have had not less than 12 months' practical, professional experience since graduation, and must be of good moral character and repute.

The preliminary examination to determine general fitness will be based on papers submitted by the candidates, reaching the Board on or before August 23, 1920, covering college record testimonials, references, and professional experience. The candidate is not required to report in person for the preliminary examination. Physical examination by a Board of Medical Examiners will be made of those candidates who qualify in the preliminary examination.

Those who qualify in the preliminary and physical examinations will take the final oral and written examinations to be held in Washington, D. C., as soon as possible after the preliminary examination papers have been passed on by the Board.

Officers of the Corps of Civil Engineers are detailed principally to the various navy yards and naval stations to supervise the work under the Bureau of Yards and Docks, Navy Department, Washington, D. C., consisting of the design and construction of all the public works of the naval establishment on shore as

well as the maintenance and repair of existing structures. The work is exceptionally varied and offers an attractive field for able and ambitious young engineers. Z-1485.

C. W. PARKS, *Chief of Bureau.*

PRODUCTION ENGINEER, technical graduate, electrical or mechanical, between thirty and forty years of age, thoroughly competent to plan, tool-up, organize and maintain efficient production on a large scale of a fractional motor, in the small motor department of a large corporation in New England; a man of strong character and personality backed by record of achievement. Z-1450.

OPERATING & CONSTRUCTING ENGINEERS with operating company in Southwest service, population of about one hundred and eighty thousand, previous experience in construction and operation of distribution systems, substations and power plants, desirable technical training essential, in applying give age, married or single, education, technical training experience, salary expected, references and when available. Z-1484.

DRAFTSMEN (2) good advancement, must be acquainted with high-tension electrical design. Capable of doing own designing preferred. Location New Jersey. Z-1489.

EXPERIENCED ELECTRICAL SUBSTATION OPERATORS having a technical training and capable of promotion. State experience, education and salary desired. Location Illinois. Z-1490.

TRANSFORMER DESIGNER, young, capable and up to date to fill position in Sydney. Good possibilities. Expenses paid to Sydney and if the man is not satisfactory, his expenses will be paid back. Location Australia. Z-1492.

ASSISTANT PROFESSOR and Instructor in Electrical Engineering. Location Kansas. Z-1503.

ENGINEERS for research and development work on radio apparatus. Applicants should have an electrical engineering degree or its full equivalent in training and experience and must have had substantial experience in radio engineering. Apply by letter only to Engineering Manager, International Radio Telegraph Company, 326 Bway. New York City, stating age, education, radio experiences, references and salary desired. Z-1504.

INDUSTRIAL PHYSICIST OR ENGINEER interested in research on electrical control problems. Location, Middle West. Salary, according to training and experience. Z-1525.

YOUNG MAN, graduate engineer, to teach physics. Location New Jersey. Z-1506.

MEN AVAILABLE

GRADUATE ELECTRICAL ENGINEER, 25, two years experience in operating before graduation. One year Sales Engineer in Mechanical and Electrical Work. Desire general electrical work with some sales opportunity. Prefer position of immediate or eventual location in Orient or South America. E-2224.

GRADUATE ELECTRICAL ENGINEER desires business or engineering position with growing concern near Boston, 6 years office and field experience in power plant and distribution design including some mechanical and civil engineering experience. B. S. Tufts College. Familiar with contract work, estimating, and power equipment. E-2225.

YOUNG MAN, age 28, single; partial technical training. Five years electrical experience, actual construction, engineering, and merchandise jobbing. Desire position with prospects for advancement to an executive position. Any Location. Available immediately. E-2226

SALES ENGINEER, with fourteen years experience large electric manufacturing company including ten years on apparatus sales and executive work. Desire position as representative of reliable company in Ontario, or executive position of business nature requiring a knowledge of engineering. E-2227.

TECHNICAL GRADUATE; in charge of electrical engineering department of large designing and contracting company. Familiar apparatus and material of electrical and allied industry, through specifying, selecting and recommending. Speak Scandinavian and German. Will consider exporting firms. E-2228.

PRACTICAL ELECTRICAL MAN, on any electrical field work. Age 21, single, 5 years practical experience, 3 years technical training. Salary $1500, exclusive of room and board expenses. Location desired Wisconsin. E-2229.

GRADUATE ELECTRICAL ENGINEER of 10 years standing from an Eastern Institution. 34, married, speak French. Experienced supervision and direction of tests, instrument work, line construction cable work, electrolysis mitigation. At present with power department of large street railway company in New York as Electrical Assistant. Salary $3400. E-2230..

ENGINEER, SUPERVISING or operating chief; position of responsibility in charge of power plants or plant and mechanical and electrical industrial equipment especially where proportionately large amount of steam and power is used in manufacturing; 20 years experience. Married, Location immaterial. Salary commensurate with position. Immediately available. E-2231.

ELECTRO MECHANICAL ENGINEER, Cornell; 2 years general electric test; 2 years inspection work at large shipbuilding plant. Desire position with good opportunity for advancement. New York City preferred. Available short notice. Salary $2400. E-2232.

ENGINEER AND MANAGER; technical graduate, eight years factory construction and field installation of electrical machinery and operation of power plants and transmission systems, two years and at present district manager of gas, water and electric properties of a large holding company. Middle West location desired; minimum salary $3300. E-2233.

POWER ENGINEER, 15 years experience. Generation, distribution and Construction in United States; Canada and England. Industrial Construction and Appraisal. Good knowledge of chemistry. Alexander Hamilton Institute Business Training. Desires responsible position with large industrial or public utility concern. Prefer New England but would consider British connection. E-2234.

ELECTRICAL ENGINEER; desires location Pacific Coast. Age 34. A. B. and E. E. degrees. Ten years with large engineering and construction company responsible for electrical estimates, designs and purchases in connection with power stations, industrial plants and various power and lighting applications. Salary $4500. E-2235.

TECHNICAL GRADUATE, 36, 5 years electric railway experience, prefer heavy traction electric railway work, but will consider any engineering work pertaining to electric traction. E-2236.

ELECTRICAL ENGINEERING TEACHER, 12 years experience at institutions of recognized standing. Position leading to head of department preferred. Broad experience in commercial engineering work. Age 35 married. Minimum $3500. E-2237.

PROFESSOR OF ELECTRICAL ENGINEERING, now engaged on electrical research and development. Desires to return to teaching in University where Engineering research can be organized. Over ten years experience in large University. During war (Major) in charge of extensive work. Minimum $4000. E-2238.

CAPABLE EXECUTIVE, Graduate Electrical Engineer, Naval Engineering Officer during war, now with government in position of responsibility in electric propulsion work, desires to connect with private manufacturing concern. Considerable efficiency and organization ability, with experience obtained from contact with many large manufacturing companies during war period. E-2239.

PROFESSOR OF ELECTRICAL ENGINEERING, broad education; Member of A. I. E. E. Thirteen years practical and teaching experience in mechanical and electrical engineering. Minimum salary $3500. Also desire temporary connection for summer months. E-2240.

ELECTRICAL ENGINEER; graduate 1917; business training, two years operation, maintenance, power plants, refrigerating machinery; lightning arrester installations. Lieutenant, Signal Corps. Telephone experience; assistant to consulting engineer, one year. Will accept responsible teaching position in engineering college, manufacturers educational department or position as electrical engineer with railway, power, or manufacturing company. E-2241.

ELECTRICAL ENGINEER, technical graduate, 2 years G. E. Test, 1½ years Construction Foreman, 1 year Second Lieutenant, 1 year laboratory instructor University. Desires employment in power work as factory Electrical Engineer. Power superintendent, or Assistant purchasing Agent. E-2242.

ASSISTANT CONSTRUCTION ENGINEER, ELECTRICAL. Technical graduate with six years of railroad, telephone and power experience. Age 27. Salary $225-250 per month. E-2243

YOUNG MAN, 24, 5 years experience electrical engineer, duties electric hoists, power and substation, radio apparatus engineering correspondent with manufacturing concern. At present assisting vice-president of public utility in valuation etc. Self educated. Initial salary $200 per month. E-2244.

ELECTRICAL ENGINEER, (B. E. 1919) desires connection Baltimore district. Experience includes investigations and re-

ports on power and transmission problems, industrial layouts, industrial sales engineering and a variety of industrial engineering problems. Position with good future desired. E-2245.

MECHANICAL AND ELECTRICAL ENGINEER 15 years experience in the design, erection and operation of power plants steam and electrically driven manufacturing machinery. Qualified as executive to handle many men in all departments. Good experience in the combustion of bituminous and anthracite coal. Operation and maintenance of extensive heavy equipment are my specialties. Salary $7500 per year. E-2246.

ELECTRICAL RAILROAD INSPECTOR with technical education. Qualified in both Electrical and Mechanical features of light and heavy traction equipment. Is experienced in D. C. and high voltage A. C. Railroading. Position in or around New York City, desired. At present employed on large railroad with A. C. trunk line electrification. E-2247.

GRADUATE ELECTRICAL ENGINEER (1909) married, age 31 desires position of greater responsibility in consulting and engineering. Has had factory and office experience, also erection repair and executive experience with large industrial corporation. Capable of handling construction erection and operation work. Salary $3000. Available at once. E-2248.

ELECTRICAL ENGINEER, 32, university graduate desires engineering position. 9 years experience in construction, design and distribution of power plants, substations, transmission lines, etc. E-2249.

TECHNICAL GRADUATE, age 42, married, Associate A. I. E. E. Three years Westinghouse test, motors and generators, year and one half erecting engineer. Eight years superintendent municipal light, power and water works. At present holding such position. Desires change offering responsible position with broader opportunities. Available at short notice. E-2250.

ELECTRICAL ENGINEERING GRADUATE with twelve years practical experience in design, construction and maintenance of steam and industrial power plants and substations in the west. Age 34, single. Desires position with manufacturing concern in or near New York. Salary $4000. E-2251.

GRADUATE ELECTRICAL ENGINEER with ten years experience in design, construction, maintenance and operation of hydroelectric and commercial electrical equipment wishes to connect with some large concern which appreciates initiative, executive and technical ability, proven dependability and personality. At present holding responsible position and in excellent standing. Reason for change purely personal. Married. Age 30. Salary about $4000 depending on location. E-2252.

EXECUTIVE MECHANICAL AND ELECTRICAL ENGINEER (Graduate 1911) of broad electrical and mechanical experience in testing of machinery, production and cost accounting. Thoroughly familiar with modern production methods, accounting, the installation and operation of scientific management. Ex-army officer. Age 32, unmarried. Would consider a sales proposition. Salary of secondary consideration to opportunity. E-2253.

ASSOCIATE MEMBER OF A. I. E. E. and certified member of several other national engineering societies who has had engineering and scientific college training now supplemented by several years practical experience with both Electrical Utility and Manufacturing Companies of East along lines of designing, experimental, research and test engineering desires a position as Electrical Engineer or similar supervisory position where a steady, ambitious person of good ability, character and habits, with wife and child can locate in permanent position. Fair living salary desired at start:—commensurate with duties and location but salary is of secondary importance to other conditions as permanency, living conditions, advancement and treatment accorded. E-2254.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (MAY 1-31 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AIRMAN'S INTERNATIONAL DICTIONARY.

Including the most important technical terms of aircraft construction, English—French—Italian—German. Edited by Mario Mele Dander. Lond., Charles Griffin & Co., Ltd. (1919). 227 pp., 6 x 4 in., cloth, 6 shillings. (Gift of J. B. Lippincott Co.)

The terms in this dictionary are classified under systematic headings, so that those relating to a particular part of the airplane are brought together, and an alphabetic index is provided.

ASBESTOS AND THE ASBESTOS INDUSTRY AND OTHER FIREPROOF MATERIALS.

By A. Leonard Summers. Lond. & N. Y., Sir Isaac Pitman & Sons, Ltd., n. d. 107 pp., illus., plates, 7 x 5 in., cloth, 2s 6d.

This little book gives a non-technical account of asbestos, its sources, varieties and uses, that is intended for users of this material and for general readers, rather than for those in search of detailed information.

AUTOMOBILE CONSTRUCTION AND REPAIR.

With Questions and Answers. By Morris A. Hall. Chicago American Technical Society. 1920. 711 pp., illus., 8 x 6 in., flexible cloth, $3.50.

In this book the various parts of the automobile are described in detail, and explicit instructions for their adjustment and repair are given. The volume is intended for owners, chauffeurs and repairmen.

CEMENT.

By Bertram Blount, assisted by William H. Woodcock and Henry J. Gillett. Lond. & N. Y., Longmans, Green & Co., 1920. 284 pp., illus., plates, tables, 9 x 6 in., cloth, $6.00.

This monograph, like its companion volumes, is intended to give a connected, balanced account of the cement industry, in the light of our scientific knowledge of the principles underlying it. Processes are explained, so far as they are necessary to elucidate principles, but no attempt is made to present minute technical details.

COAL MEN OF AMERICA.

Arthur M. Hull, Editor-in-Chief, Sydney A. Hale, Associate Editor. Chic., The Retail Coalman, 1918. 506 pp., portraits, 12 x 9 in., cloth, $10.

A brief historical and descriptive account of the coal trade in each state is given, followed by alphabetical lists of those engaged in it. The business connections of these men are noted and many portraits are included. The coal trade, not coal mining, is the industry under consideration.

CREATIVE CHEMISTRY.

Descriptive of Recent Achievements in the Chemical Industries. By Edwin E. Slosson. N. Y., The Century Co., 1920. 311 pp., illus., chart, plates, 8 x 6 in., cloth, $2.50.

In this work, Dr. Slosson gives a readable account of some of the great results of modern chemical activity, as well as some of the big problems which engage attention today. The book is intended for general readers and as supplementary reading for college students.

DYKE'S AUTOMOBILE AND GASOLINE ENGINE ENCYCLOPEDIA.

Treating on the Construction, Operation and Repairing of Automobiles and Gasoline Engines—also Trucks, Tractors, Airplanes and Motorcycles.

By A. L. Dyke. Twelfth edition. St. Louis, A. L. Dyke. 940 pp., illus., charts, 10 x 7 in., cloth, $6.

This well-known book has undergone its annual revision and has also been enlarged by the addition of material on motor trucks, tractors, motorcycles and airplanes. With its wealth of illustrations and its clear, practical information on all subjects connected with automobile operation and repair, it is well named an encyclopedia of the subject.

A FEW SECRETS OF THE METALLURGIST SIMPLY TOLD.

By Gerald W. Hinkley. First edition. Atlas Crucible Steel Co., Dunkirk, N. Y. 99 pp., 7 x 5 in., cloth, $1.00.

The question discussed by the author is "Why does steel harden?" This he answers by a brief non-technical explanation of the allotropic theory of iron and steel, suited to those without metallurgical training. About half of the book is devoted to alloy steels.

FORGE-PRACTISE AND HEAT TREATMENT OF STEEL.

By John Lord Bacon. Third edition, revised & enlarged by Edward R. Markham. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 418 pp., illus., tables, 8 x 5 in., cloth, $1.75.

This is a textbook to accompany a course in forge practise, which explains the principles and provides a suitable set of exercises, but does not attempt to give minute instructions for making tools. The present edition has been enlarged by the inclusion of instruction in the heat treatment of steel.

FURTHER INCIDENTS IN THE LIFE OF A MINING ENGINEER.

By E. T. McCarthy. Lond., George Routledge and Sons, Ltd.; N. Y., E. P. Dutton & Co., 1920. 400 pp., por., 9 x 6 in., cloth, $7.00. (Gift of E. P. Dutton & Co.)

The success of Mr. McCarthy's previous volume, "Incidents in the Life of a Mining Engineer", has caused him to continue his account of his travels in little known countries. In "Further Incidents" he describes his adventures in Yucatan, Swaziland, China, the Malay States, Dutch West Borneo, Korea, Siberia and Siam.

As was the case with its predecessor, the proceeds of the sale of the book will be devoted to the St. Dunstan's Hospital for the Blind.

HAND BOOK OF NATURAL GAS.

By Henry P. Westcott. Third edition, 1920. Erie, Penn., The Metric Metal Works. 725 pp., illus., plates, charts, tables, 8 x 5 in., cloth, $3.75.

The intention of this work is to supply a one-volume manual covering the entire industry in a practical way. It begins with a brief statement of the geology of the gas fields, followed by a history of the industry and then proceeds successively to the properties of gases, field work, measurement of gas wells, pipe line construction and capacity gas compression, measurement, regulation, distribution and consumption. Casing head gasoline, the carbon black industry, helium and acetylene welding are also discussed. The present edition has been revised and enlarged.

HARDENING, TEMPERING, ANNEALING AND FORGING OF STEEL.

Including Heat Treatment of Modern Alloy Steels. A Complete Treatise on the Practical Treatment and Working of High and Low Grade Steel, comprising the Selection and and Identification of High and Low Carbon Steel, and Modern Chrome-Nickel and Chrome-Vanadium Alloys; the Most Modern Hardening, Tempering, Annealing and Forging Processes, the Use of Gas Blast and Electric Furnaces, and Heating Machines.

By Joseph V. Woodworth. Fifth edition. N. Y., The Norman W. Henley Publishing Co., 1919. 321 pp., illus., tables, 9 x 6 in., cloth, $3.

The author has prepared a compendium of practical information on the subjects mentioned, based on trade literature and personal experience, for the use of mechanics and other users of steel. The present edition has been revised and enlarged, and a section treating of the newer alloy steels has been added.

INTERNAL-COMBUSTION ENGINES.

Their Principles and Application to Automobile, Aircraft and Marine Purposes. By Wallace L. Lind. Boston, Ginn & Co. (copyright 1920). 225 pp., illus., chart, 8 x 6 in., cloth, $2.20.

This is a brief, practical, up-to-date text for students, covering the theory and operation of these engines, but omitting the question of design.

A KINETIC THEORY OF GASES AND LIQUIDS.

By Richard D. Kleeman. First edition. N. Y., John Wiley & Sons— Inc.; Lond., Chapman & Hall, Ltd., 1920. 272 pp., tables, 8 x 5 in., cloth, $3.00.

The object of this book is to formulate a kinetic theory of certain properties of matter, which shall apply equally well to matter in any state. By considering atoms or molecules as mere centers of forces of attraction and repulsion, instead of as elastic spheres and by modifying the definition of the free path of a molecule so that the exact nature of molecular interaction is not involved, it is possible to lay the foundation of a general kinetic theory which applies to matter in any state, and which furnishes a number of important formulas.

PIEUX ET SONNETTES.

By Edouard Noe and Louis Troch. Paris, Gauthier-Villars et Cie, 1920. 348 pp., illus., 10 x 7 in., paper, 20 francs, plus 50 per cent temporary increase

This work is a theoretical and practical discussion of piles and pile-driving, intended for engineers and architects. The first chapter treats of wooden piles, the second of metallic piles and the third of the different varieties of concrete piles, their advantages and disadvantages. Chapter four discusses metal sheet-piling. The theory of pile-driving is then studied, followed by a description of the various types of pile-drivers and of the method of driving by means of a water-jet. The volume ends with a study of the equilibrium of piles and notes on the proper choice of piles.

THE RUNNING AND MAINTENANCE OF THE MARINE DIESEL ENGINE.

By John Lamb. Lond., Charles Griffin & Co., Ltd.: Phila., J. B. Lippincott Co., 1920. 231 pp., illus., plates, 7 x 4 in., cloth, 8s 6d. (Gift of J. B. Lippincott Co.)

This is a practical manual, intended to prepare marine engineers who have not had previous experience with oil engines, so that they can qualify for positions on motorships. For this purpose the author describes the usual types of marine Diesel engines, the defects which have developed during operation and the methods that he has used to remedy them.

TECHNICAL WRITING.

By T. A. Rickard. First edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 178 pp., 8 x 5 in., cloth, $1.50.

Mr. Rickard's primary object is to awaken the interest of engineers in the importance of the proper use of language. His volume is a discussion of the subject, in which particular attention is given to the usual faults of technical writing, as he has observed them during his long experience as an editor. His rules are simple and definite, and their use is illustrated by numerous examples, so that the book will prove a useful guide to authors.

A TEXT-BOOK OF INORGANIC CHEMISTRY.

Edited by J. Newton Friend. Volume IX, Part 1. Cobalt, Nickel, and the Elements of the Platinum Group. By J. Newton Friend. Lond., Charles Griffin & Co., Ltd., Phila., J. B. Lippincott Co., 1920, 367 pp., tables, 9 x 6 in., cloth, 18s.

This instalment of this important reference work covers the eighth group of the Periodic Table, with the exception of iron. Like the previous volumes, it gives a concise, yet full, account of our present knowledge of these elements and their inorganic compounds, accompanied by numerous references to the leading works and monographs that treat of them.

ZINC AND ITS ALLOYS.

By T. E. Lones. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd. 127 pp., illus.; plate, 7 x 5 in., cloth, 2s 6d.

This is a concise, readable account of the occurrence, recovery and uses of zinc, intended for persons engaged in the zinc trade or in search of general information about the metal.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Chicago.—May 12, 1920, Fullerton Hall, Art Institute. Joint meeting with Electrical Section of Western Society of Engineers. Election of officers as follows: Chairman, J. R. Bibbins; Secretary, M. M. Fowler. Subject: "City Building and Transportation." Speaker: Mr. J. R. Bibbins, of The Arnold Company, Chicago. Attendance 250.

Denver.—May 8, 1920, Kenmark Hotel. Business meeting and election of officers as follows: Chairman, D. C. McClure; Vice-Chairman, J. C. Lawler, Secretary-Treasurer, R. B. Bonney. Attendance 28

Detroit-Ann Arbor.—May 12,1920, Board of Commerce. Subject: "The Electric Furnace in the Metallurgical Industry." Speaker: E. L. Crosby, of the Detroit Electric Furnace Co. Attendance 65.

Erie.—May 17, 1920, Commerce Rooms. Subject: "Some Present Day Problems in Engineering Research." Speaker: Professor V. Karapetoff, of Cornell University. Attendance 55.

Indianapolis-Lafayette.—May 21, 1920, Subject: "The Coming Science of Acoustical Engineering." Speaker: Professor V. Karapetoff, of Cornell University. Attendance 50.

Madison.—June 2, 1920, Engineering Bldg., University of Wisconsin. Election of officers as follows: Chairman, G. C. Neff; Secretary, H. M. Crothers. Subject: "Submarine Detection." Speaker: Professor M. Mason, of the University of Wisconsin. Attendance 30.

Panama.—May 8, 1920, Balboa Heights, C. Z. Subject: "Light, Lamps and Lighting Accessories." Speaker: Robert E. Hattis. A moving picture film showing the method of manufacturing National Mazda Lamps was projected and 31 views showing installations by the National X-Ray Reflector Company were shown. Attendance 20.

May 22, 1920, Hotel Corco, Panama. Business meeting and election of officers as follows: Chairman, Baxter R. Grier; Vice-Chairman, Elbert C. McDonald; Secretary-Treasurer, M. P. Benninger. Attendance 26.

Philadelphia.—June 7, 1920, Howard McCall Field. The afternoon was given over to golf. quoits and tennis matches between individual members, and two baseball games, followed by annual dinner, and election of officers as follows: Chairman, Chas. E. Bonine; Managers, C. W. Fisher, Baxter Reynolds, L. J. Costa and W. D. Carr; Secretary, R. B. Mateer. Attendance 117.

Pittsburgh.—May 11, 1920, Chamber of Commerce. Subject: "Ship Propulsion." Speaker: W. E. Thau, of the W. E. & M. Co. Attendance 57.

Pittsfield.—May 27, 1920, Masonic Temple. Subject: "What Industrial Workers are Really Thinking About." Speaker Mr. Whiting Williams. Director of Personnel, Hydraulic Press Steel Co., Cleveland, O. Attendance 200.

Portland.—May 11, 1920, University Club. The tentative program for the Pacific Coast Convention was discussed. Subject: "The Swan Island Project." Speaker: Mr. Robert G. Dieck. Refreshments were served. Attendance 51.

Seattle.—May 18, 1920, Arctic Club Assembly. Business meeting, followed by presentation of paper on "Methods Used in Laying Submarine Cables," by Mr. H. J. Sheppard, of The Pacific Tel. & Tel. Co. Attendance 75.

Toronto.—May 7, 1920. Engineers' Club. The meeting took the form of a "Question Box" discussion on a number of subjects suggested by the local members as follows: Wireless Transmission, A-C. Generators, Induction Generators, Rates for Electrical Energy, Relationship Between Technical and Commercial Phases of Electrical Industry, and Power Transformers. Attendance 68.

Worcester.—May 25, 1920, Worcester Polytechnic Institute. Subject: "Notes on Electric Power Conditions During the War, in New England and on the Pacific Coast." Speaker: Mr. George F. Sever. Attendance 55.

PAST BRANCH MEETINGS

Carnegie Institute of Technology.—May 27, 1920, Machinery Hall, C. I. T. Election of officers for 1920-21 as follows: Chairman, A. J. Hanks; Vice-Chairman, E. A. Brand; Secretary, W. S. Andrews. Subjects of the meeting: "Electrification of Railroads" by L. H. Hale '20, and "New Possibilities in Hydro-Electric Development" by F. I. Lawson '20. Attendance 60.

University of Cincinnati.—May 25, 1920, Engineering Building. Subject: "What is Electricity." Speaker: C. W. Coleman. University of Cincinnati. Attendance 72.

University of Kentucky.—May 12, 1920, Mechanical Hall. Business meeting, followed by a talk on "Inductive Effects of Transmission Lines" by Professor E. A. Bureau. Attendance 20.

University of Maine.—May 26, 1920, Lord Hall. Election of officers as follows: Chairman, Conan Priest; Secretary, Foster B. Blake; Treasurer, Virgin Trouant. Talks as follows: "Application of Electricity to Practical Lines" and "The Relation of the Engineer to His Work" by Mr. Davis of the B. R. & E. Co.; "Paper Making" by I. E. Craig. Attendance 28.

Massachusetts Institute of Technology.—May 27, 1920, Boston, Mass. Annual banquet; installation of new officers as follows: Chairman, D. B. McGuire; Secretary, M. C. Hall; Treasurer, L. R. Janes. Addresses were given by Acting President Elihu Thomson. Prof. D. C. Jackson and Prof. W. H. Timbie. Short talks were given by Professors A. E. Kennelly, W. S. Franklin, T. H. Dillon, and the incoming officers. Attendance 100.

Michigan Agricultural College.—June 3, 1920, Olds Hall of Engineering. Subject: "Direct-Current Machine Design." Speaker: Mr. H. L. Smith, of the Howell Motor Co., Attendance 24.

University of Michigan.—May 26, 1920, Engineering Bldg. Business meeting and election of officers as follows: Chairman, L. E. Frost; Vice-Chairman, J. H. Pilkington; Secretary, Leon A. Sears; Treasurer, M. B. Covill. Attendance 15.

School of Engineering of Milwaukee.—May 21, 1920. Subject: "Fundamental Principles of Modern Telephony." Speaker: Mr. W. J. Elmore, of the Wisconsin Telephone Co. Attendance 41.

Montana State College.—June 7, 1920, Assembly Hall. Subject: "Industrial Relations." Speaker: Mr. A. D. Stuart of the W. E. & M. Co. Attendance 77.

June 9, 1920.—Electrical Lecture Room. Election of officers as follows: Chairman, John L. Hastings; Vice-Chairman, Fred Cruzen, Secretary, J. A Thaler. Attendance 37.

University of North Carolina.—May 10, 1920. Subject: "The Grounding of Secondaries." Speaker: Mr. L. V. Sutton, of the Carolina Light & Power Co. Attendance 42.

May 31, 1920. Subjects: "Methods of Predetermining Motor Characteristics" by W. E. Merritt, and "The Senior Project" by C. M. Hazelhurst. Attendance 54.

Ohio State University.—May 25. 1920, Ohio Union. Banquet, at which election of officers for 1920-21 was held as follows: Chairman, S. S. Hunt; Vice-Chairman, J. C. Steffan; Secretary-Treasurer, R. H. Kaspar. The members then adjourned to Robinson Laboratory where an illustrated talk on "Automatic Telephone Circuits" was given by Mr. S. B. Williams, of the Western Electric Co. Attendance 34.

University of Oklahoma.—May 26, 1920, Engineering Bldg., Election of officers as follows: Chairman, M. G. Ross; Vice-Chairman, Archie Wallace; Secretary, Virgil Pendleton; Treasurer, Fred Huckaby. Attendance 39.

University of Pennsylvania.—May 10, 1920, Subjects: "Electrical Precipitation" by Mr. Shakeshaft, and "Household Electrical Appliances" by Mr. Zippler.

May 17, 1920. Subject: "Transmission Lines" by Mr. Greenstein.

May 24, 1920. Subject: "Development of Transformer" by Mr. Ten Broek. Total attendance 150.

University of Pittsburgh.—May 18, 1920. Paper: "Wireless Telephony." Speakers: Messrs. G. B. Anderson and J. C. Wolfe. Attendance 28.

May 25, 1920. Paper: "Vacuum Tubes." Speakers: Messrs. C. R. McGann and W. B. Jones. Attendance 25.

Purdue University.—April 20, 1920, Electrical Building. Three reel motion picture entitled: "The Story of a Fire" was presented by the Goodyear Rubber Company. Attendance 89.

May 22, 1920, Electrical Building. Subject: "The Coming Science of Acoustical Engineering." Speaker: Professor V. Karapetoff, of Cornell University. Attendance 95.

Stanford University.—April 28, 1920. Subject: "The Electrical Engineering of Radio Telegraphy." Speaker: Mr. Pratt, of the Federal Telegraph Company. Attendance 22.

University of Texas.—May 8, 1920. An interesting program on Electric Railways was given by the committee in charge, and Prof. J. M. Bryant gave a short interesting talk on "Where the Nickle Goes." A paper on "The Development of the Electric Locomotive" was presented by Mr. E. P. Price, and another on "The Development of the Electric Locomotive for Passenger Service on the Mountain Division of the C. M. & St. Paul Railway" was read by Mr. L. B. Walker. Both of these papers were illustrated by lantern slides. Mr. W. J. Weeg gave an interesting talk on "Alternating Current vs. Direct Current for Electric Railways. Attendance 21.

Virginia Military Institute.—June 2, 1920, organization meeting. Election of officers as follows: Chairman, H. C. Land; Secretary-Treasurer, L. Womeldorf. Attendance 17.

University of Washington.—May 4. 1920, Forestry Hall. Subject: "Electrification of the Chicago, Milwaukee & St. Paul Railway." Speaker: Mr. A. B. Van Dusen. Mr. Van Dusen illustrated his lecture with about one hundred slides. A three reel film entitled "The King of the Rails" was also shown. Attendance 91.

Washington State College.—May 14, 1920, Mechanic Arts Bldg. Business meeting, and election of officers as follows: Chairman, Chester H. Eitel; Secretary, Albert Hanson; Treasurer, Claude Kriesher. Attendance 16.

University of Wisconsin.—April 14, 1920. Engineering Bldg. Subject: "Central Stations Problem." Speaker: Mr. Newton, of the Madison Gas & Electric Company. Attendance 35.

May 12, 1920, Engineering Bldg. Subject: "Electric Train Control in the New York Subways." Speaker: Mr. Harold P. S. Day. Attendance 40.

June 9, 1920, Engineering Bldg. Election of officers for 1920-21 as follows: Chairman, R. E. Hantzsch; Secretary-Treasurer, E. D. Johnson.

Yale University.—May 18, 1920, Dunham Laboratory of E. E. Subject: "The Stevenson Power Plant." Speaker: Mr E. J. Amberg, of the Connecticut Light & Power Company. Attendance 150.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held on June 7 and 21, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

Recommended by the Board of Examiners June 7, 1920

To Grade of Fellow

FERNOW, BERNHARD E., JR., Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

PIERCE, ARTHUR G., Manager, Central District, Cutler-Hammer Mfg. Co., Pittsburgh, Pa.

RICE, RALPH H., Principal Assistant Engineer, Board of Supervising Engineers, Chicago, Ill.

To Grade of Member

BARRON, JACOB T., General Supt. of Production, Public Service Electric Co., Newark, N. J.

BATCHELLER, WILLIS T., Electrical and Mechanical Engineer, Seattle Municipal Light and Power System, Seattle, Wash.

BROWN, L. E., Superintendent, Springfield Light, Heat & Power Co., Springfield, O.

HILL, WILLIAM S., Supt. Light & Power, Springfield Gas & Electric Co., Springfield, Mo.

KILNER, RALPH H., Commercial Engineer, Westinghouse Electric & Mfg. Co., Chicago Ill.

KOONTZ, JOHN A., JR., Electrical Engineer, Great Western Power Co., San Francisco, Cal.

MCKENZIE, DANIEL A., Asst. Engineer, Operating Dept., Hydro-Electric Power Commission, Toronto, Ont.

O'CONNELL, WILLIAM T., Estimator & Designer, Elec. Div., Panama Canal, Balboa Heights, C. Z.

PEARCE, WALTER C., Supt., Electric Dept., Syracuse Lighting Co., Syracuse, N. Y.

PRINDLE, EDWIN J., Senior Partner, Prindle, Wright & Small, New York, N. Y.

SMITH, HAROLD L., Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

WESTMAN, ADOLF J., Electrical Engineer, Montreal Tramways Co., Montreal, Canada.

Recommended by the Board of Examiners June 21, 1920

To Grade of Fellow

BEEUWKES, REINIER, Electrical Engineer, Chicago, Milwaukee & St. Paul R. R. Co., Seattle, Wash.

MORTON, ROBERT B., Electrical Engineer with Toltz, King & Day, St. Paul, Minn.
MURPHY, GEORGE R., Manager, Pacific District, Electric Storage Battery Co., San Francisco, Cal.

To Grade of Member

BAKER, FRANK J., Vice-President, Public Service Co. of Northern Illinois, Chicago, Ill.
BALDWIN, ROBERT L., Electrical & Mechanical Engineer, Burns & McDonnell, Kansas City, Mo.
BARNES, DONALD C., Manager, Seattle Division, Puget Sound Power & Light Co., Seattle, Wash.
BERGSTROM, CARL O., Manager, Electrical Dept., B. F. Sturtevant Co., Hyde Park, Mass.
BRILL, OSCAR C., Office of Chief Engineer, American Telephone & Telegraph Co., New York, N. Y.
DURAND, WILLIAM F., Professor of Mechanical Engineering, Standford University, Stanford University, Cal.
EVANS, CLARENCE T., Development Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
EVANS, LLEWELLYN, Superintendent of Electric Works, City of Tacoma, Wash.
FAWELL, THOMAS A., Chief Draftsman, Anderson, Meyer & Co. Ltd., Shanghai, China.
FERRIS, LIVINGSTON P., Electrical Engineer, Dept. of Development & Research, American Telephone & Telegraph Co., New York, N. Y.
GAFFEY, JOHN J., Assistant Engineering Manager, Harry M. Hope Engineering Co., Boston, Mass.
HURLEY, WALLACE P., Sales Engineer, Westinghouse Electric & Mfg. Co., New York, N. Y.
McALPINE, DOUGALD D., Contract Engineer, Canadian General Electric Co., Toronto, Ont.
MILLER, ALVIN A., Manager, Power & Railway Divisions, Westinghouse Elec. & Mfg. Co., Seattle, Wash.
OETTING, O. W. A., Chief Engineer, Willard Storage Battery Co., Cleveland, O.
PACE, GORDON, District Operating Engineer, Hydro Electric Power Commission of Ontario, Toronto, Ont.
READ, ERNEST K., Circuit Breaker Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
ROBLEY, ROY R., Operating Engineer, Portland Railway, Light & Power Co., Portland, Ore.
VAN HORN, IRVING H., Physicist, Lamp Development Lab., National Lamp Works of General Electric Co., Nela Park, Cleveland, O.
WARNER, RUSSELL G., Instructor in Electrical Engineering, Yale University, New Haven, Conn.
ZIMA, LUDWIG A., Assistant Cable Engineer, Interborough Rapid Transit Co., New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member, objecting to the election of any of these candidates should so inform the Secretary before July 31, 1920.

Adams, Charles W., Saginaw, Michigan
Andres, Paul G., E. Lansing, Mich.
Bankus, John, Portland, Oregon
Benington, William F., Syracuse, N. Y.
Betts, Andrew G., Tacoma, Wash.
Blanton, Burt C., Dallas, Texas
Boring, Herbert A., Seattle, Wash.
Brainard, Charles D., Chicopee, Mass.
Brown, Robert Q., Seattle, Wash.
Bryant, Le Roy C., Chicopee, Mass.
Campbell, Allan B., Des Moines, Iowa
Carpenter, James W., St. Louis, Mo.
Casey, Francis, Chicago, Ill.
Chamberlain, Leon H., San Francisco, Cal.
Cobb, Frank E., St. Louis, Mo.
Cockburn, Donald, Boston, Mass.
Coffin, Frank C., Worcester, Mass.
Conrad, Lester L., Los Angeles, Cal.
Corson, Le Roy, Long Island City, N. Y.
Counts, Hilda, E. Pittsburgh, Pa.
Crawford, Vernon W., Pittsfield, Mass.
Denn, Edward J., Springfield, Mass.
Eckert, William S., Hastings-on Hudson, N. Y.
Edwards, Weightman, New York, N. Y.
Fairfield, Donald H., Kenosha, Wis.
Fisher, William H., Akron, Ohio
Fleming, Samuel W., Harrisburg, Pa.
Fletcher, John A., Vancouver, B. C.
Flowers, William E., (Member), Atlanta, Ga.
Frankel, Charles B., Chicago, Ill.
Franklin, Townsend U., New York, N. Y.
Friday, Casper S., Schenectady, N. Y.
Gifford, Clarence C., San Pedro, Cal.
Glass, Howard G., Baltimore, Md.
Godwin, Jimmie J., St. Louis, Mo.
Govier, Charles E., State College, Pa.
Grant, Royal E., Dracut, Mass.
Gregory, Philip S., Montreal, Quebec
Guy, Richard W., Ottawa, Canada.
Henyan, George W., Schenectady, N. Y.
Herrold, Charles D., San Jose, Cal.
Hills, Charles B., Bathurst, N. B.
Hobson, Albert, Dallas, Texas
Hofert, Fred A., Chicago, Ill.
Hood, Clifford F., Worcester, Mass.
Hopkins, Henry D., Akron, Ohio
Hrubes, James A., Chicago, Ill.
Hubbert, William, Seattle, Wash.
Hult, George A., Sioux Falls, S. Dak.
Insel, Emanuel M., New York, N. Y.
Irland, George A., Sparrows Point, Md.
Jahn, Emil, New York, N. Y.
Jansky, Cyril M., Jr., Minneapolis, Minn.
Johnson, Clarence L., San Francisco, Cal.
Johnson, Tomlinson F., Jr., (Member), Atlanta, Ga.
Kawabata, Itsuo, Boston, Mass.
Keiser, William P., St. Louis, Mo.
Krasnoff, Nathaniel, Annapolis, Md.
Kyle, George L., Niagara Falls, N. Y.
Lane, Robert S., Orange, N. J.
Lang, William I., Jr., New York, N. Y.
Lindell, Arthur G., Chicago, Ill.
Malloy, William E., New York, N. Y.
Manchester, Mark D., (Member) Dawson, Yukon Territory
Meeker, Royal, Pittsfield, Mass.
Merrill, Zadoc E., Olympia, Wash.
Meyer, Grover C., New York, N. Y.
Millan, A. M. M., Seattle, Wash.
Moses, Marcus H., New York, N. Y.
McCain, Vernon E., Tacoma, Wash.
McFarland, George I., Salt Lake City, Utah
McKeen, Ernest E., Portland, Oregon
McKenzie, Ernest F., Schenectady, N. Y.
O'Brien, Brian, New Haven, Conn.
O'Leary, Joseph T., New York, N. Y.
Peck, Henry S., (Member), Seattle, Wash.
Pilcher, Basil B., Philadelphia, Pa.
Ploetz, Charles M., Milwaukee, Wis.
Prescott, Clifton S., Chicago, Ill.
Price, Tyler, G., Chicago, Ill.
Pritzker, Asher, Toronto, Ont.
Quinn, John T., New York, N. Y.
Rhudy, James T., Lexington, Va.
Roddey, Marvin M., Cleveland, Tenn.
Roell, Frank A., Seattle, Wash.
Ryder, Harry M., E. Pittsburgh, Pa.
Rurey, Burdett F., Shorewood, Wis.
Schweizer, Albert C., New York, N. Y.
Scott, James P., Pittsburgh, Pa.

Self, Wayne K., Weirton, W. Va.
Shoemaker, Guy T., (Member), Davenport, Iowa
Skinner, William E., Milwaukee, Wis.
Smallidge, Frank E., Wenatchee, Wash.
Smith, David M. B., McGill, Nevada
Starkey, William C., Mansfield, O.
St. Clair, Harry, Chattanooga, Tenn.
Tait, Andrew S., (Member), Montreal, Que.
Thompson, Charles S., Wilmington, Del.
Underwood, Cecil H., Schenectady, N. Y.
Vodicka, Frank J., Edgewood, Pa.
Wagner, C. E., Portland, Oregon.
Watson, Leon A., Cleveland, Ohio
Waugh, Louie E., Detroit, Mich.
Webster, Clarence A., Hog Island, Pa.
Webster, Marshall, Oak Park, Ill.
Wessels, Louis H., Kearny, N. J.
White, Bryant, (Member), Lynchburg, Va.
Whiteman, Ralph A., Johnstown, Pa.
Widrig, John, Seattle, Wash.
Wiggin, Parker E., E. Pittsburgh, Pa.
Williamson, Harold P., Chicago, Ill.
Winter, Parker D., Wenatchee, Wash.
Wolfe, Nelson B., New York, N. Y.
Wood, Harold B., Roundup, Mont.
Woodcock, Vincent J., Worcester Mass.
Total 115

Foreign

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Bowles, Cecil J. V., (Member), Parnahyba, Sao Paulo, Brazil
Briggs, Arthur P., Barranquilla, Colombia, S. A.
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Gomes, Francisco, Rio de Janeiro, Brazil
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Total 27

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11576 Hale, Laurence H., Carnegie Institute of Technology
11577 Schweitzer, George E., Pennsylvania State College
11578 Nelson, Clyde A., Pennsylvania State College
11579 Lyman, Arthur F., Wentworth Institute
11580 Bagg, Raymond J., Pratt Institute
11581 Greiner, Joseph A., Murray Hill Trade School
11582 Intemann, William F., Pratt Institute
11583 Mickey, Ralph S., Pennsylvania State College
11584 Moss, John, New York Electrical School
11585 Speir, William P., Georgia School of Technology
11586 Humrickhouse, Ralph R., Case School of Applied Science
11587 Porter, Frederick M., Lehigh University
11588 Pearson, James W., Johns Hopkins University
11589 Beck, Herbert H., University of Wisconsin
11590 Malone, John F., Pratt Institute
11591 Lincks, Meorge F., Pratt Institute
11592 Brownlee, James L., Pennsylvania State College
11593 Girard, Adolph G., Leland Stanford Jr., University
11594 Thayer, Alfred H., Leland Stanford Jr., University
11595 Willcox, John F., Leland Stanford Jr., University
11596 Pardee, Starr C., Leland Stanford Jr., University
11597 Marquis, Vernon, Leland Stanford Jr., University
11598 Swift, Charles, Jr., Leland Stanford Jr., University
11599 Fink, David, Murray Hill Evening Trade School
11600 Goodman, Richard J., Pratt Institute
11601 Basta, Carlo, Pratt Institute
11602 Joss, Clifford F., Kansas State Agricultural College
11603 Leiby, Charles W., Pennsylvania State College
11604 Kenney, Wendell L., University of Illinois
11605 Yanuzzi, Angelo, Jr., Penn. State College
11606 High, Selden F., University of Cincinnati
11607 Cuttrell, William R., Stevens Institute of Technology
11608 Howe, Kasson, Yale University
11609 Flynn, William T., Worcester Polytechnic Institute
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11611 Hyman, William N., Columbia University
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11645 Bremner, William, B., Pratt Institute
11646 Keenan, Arthur J. Jr., Pratt Institute
11647 Ingraham, Dwight M., University of Maine
11648 Roth, Frederick C., Purdue University
11649 Yang, Soa L., Mass. Institute of Technology
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*Deceased.

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Chicago	A. F. Riggs	A. C. King, 8 So. Dearborn St., Chicago, Ill.
Cleveland	B. W. David	W. D. Smoot, Willard Storage Battery Co., Cleveland, Ohio.
Denver	H. S. Evans	R. B. Bonney, 603 Wyoming Bldg., Denver, Colo.
Detroit-Ann Arbor	J. C. Parker	C. E. Wise, 845 Book Bldg., Detroit, Mich.
Erie	J. C. Barry	P. B. Mansfield, Lawrence Park, Erie, Pa.
Fort Wayne	C. I. Hall	O. B. Rinehart, 1211 W. Jefferson Street, Fort Wayne, Ind.
Indianapolis-Lafayette	J. Lloyd Wayne	D. C. Pyke, Public Service Commission, State House, Indianapolis, Ind.
Ithaca	Alexander M. Gray	John G. Pertsch, Jr., Cornell Univ., Ithaca, N. Y.
Los Angeles	Clem A. Copeland	R. W. Sorensen, Throop College of Technology, Pasadena, Cal.
Lynn	A. K. Warren	Fred E. Ewart, General Electric Company, West Lynn, Mass.
Madison	G. C. Neff	H. M. Crothers, University of Wisconsin, Madison, Wis.
Milwaukee	H. P. Reed	F. J. Mayer, Wisconsin Tel. Co., Milwaukee, Wis.
Minnesota	Fred Dustin	Leo H. Cooper, 200 Builders Exch., Minneapolis, Minn.
New York	H. W. Buck	H. A. Pratt, W. E. & M. Co., 165 Broadway, New York
Panama	Baxter R. Grier	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	C. E. Clewell	Ross B. Mateer, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.
Pittsburgh	B C Dennison	W. L. Shafer, Rm. 522, 416-7th Ave., Pittsburgh, Pa.
Pittsfield	R. E. Wagner	N. F. Hanley, Gen. Elec. Co., Pittsfield, Mass.
Portland, Ore.	E. F. Whitney	W. C. Heston, Portland Ry. Lt. & Pr. Co., Portland, Ore.
Providence	R. W. Eaton	F. N. Tompkins, Brown University, Providence, R. I.
Rochester	J. W. Morrison	H. J. Schiefer, Jr., 312 E. & B. Bldg., Rochester, N. Y.
St. Louis	G. A. Waters	Stanley Stokes, Union Elec. Lt. & Pr. Co., St. Louis, Mo.
San Francisco	W. G. Vincent	A. G. Jones, 809 Rialto Building, San Francisco, Cal.
Schenectady	C. S. Van Dyke	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle	G. E. Quinan	W. T. Batcheller, Seattle Lt. & Pr. System, Seattle, Wash.
Spokane	J. E. E. Royer'	L. J. Pospisil, Washington Water Power Co., Spokane, Wash.
Toledo	W. A. Hill	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto	Ashton B. Cooper	Daniel M. Fraser, Canadian General Electric Co., Toronto, Ont.
Utah	Markham Cheever	H. T. Plumb, General Electric Co., Newhouse Bldg., Salt Lake City, Utah.
Urbana	Morgan Brooks	E. A. Reid, Univ. of Illinois, Urbana, Ill.
Vancouver	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C.	Milton M. Flanders	E. T. Walker, Bliss Electrical School, Takoma Park, Washington, D. C.
Worcester	C. R. Oliver	Dean J. Locke, 125 Salisbury St., Worcester, Mass.

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Arkansas, Univ. of, Fayetteville, Ark.	J. C. Black	S. E. Hollabough
Armour Institute, Chicago, Ill.	W. M. Seyferlich	H. D. Stevers
Brooklyn Poly. Inst., Brooklyn, N. Y.	T. C. Shwab	A. H. Wehle
Bucknell Univ., Lewisburg, Pa.	H. C. Lucus	L. F. Worthington
California Inst. of Tech. Pasadena, Cal.	R. M. Otis	D. D. Smith
California, Univ. of, Berkeley, Cal.	E. M. Brown	R. B. Stewart
Carnegie Inst. of Tech., Pittsburgh, Pa.	A. J. Hanks	W. S. Andrews
Cincinnati, Univ. of, Cincinnati, O.	R. S. Redmon	C. B. Hoffmann
Clarkson College of Tech., Potsdam, N. Y.	E. R. Taylor	H. C. Cohn
Clemson Agri. Col., Clemson College, S. C.	J. B. Fitzgerald	J. F. McHugh
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Michigan Agri. Col., East Lansing, Mich.	M. B. Rann	J. F. Van Ark
Michigan, Univ. of, Ann Arbor, Mich.	L. E. Frost	L. A. Sears
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Missouri, Univ. of, Columbia, Mo.	A. C. Lanier	F. H. Miller
Montana State Col., Bozeman, Mont.	J. L. Hastings	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State Col., West Raleigh, N. C.	D. A. Floyd	H. W. Allsbrook
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Notre Dame, Univ. of, Notre Dame, Ind.	Frank Miles	Wm. L. Wenzel
Ohio Northern Univ., Ada, O.	E. A. Erdman	J. W. Ulrey
Ohio State Univ., Columbus, O.	S. S. Hunt	R. H. Kaspar
Oklahoma A. & M. Col., Stillwater, Okla.	Earl Gray	W. C. Lane
Oklahoma, Univ. of, Norman, Okla.	M. G. Ross	Virgil Pendleton
Oregon Agri. Col., Corvallis, Ore.	Roy C. Avrit	W. D. Olson
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Queen's University, Kingston, Ont.		
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. B. Raynor
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Texas, Univ. of, Austin, Tex.	W. J. Miller	Clyde Young
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Virginia Poly. Inst., Blacksburg, Va.	L. D. Fry	R. W. Harvey
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Washington Univ. St. Louis, Mo.	Edw. Bowles	F. W. Schramm
Washington, Univ. of, Seattle, Wash.	G. R. Rice	McKinley Donovan
West Virginia Univ., Morgantown, W. Va.	H. J. Walls	M. Wilcoxen
Wisconsin, Univ. of., Madison, Wis.	R. E. Hantzsch	E. D. Johnson
Yale University, New Haven, Conn.	H. A. Haugh, Jr.	F. J. Hubbell

*Inactive at present

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An Engineering Analysis of the Labor Problem

President's Address*

BY CALVERT TOWNLEY

THE Constitution prescribes that the President must deliver an address at the Annual Convention,—whether you want to hear it or not. It has been sometimes customary for the Executive who is about to retire from office to summarize the achievements of his term. It has seemed to me that these have been better chronicled as they occurred in the pages of your JOURNAL. The pastime of prophecy has some attractions, but is of doubtful value, and somewhat dangerous as well. The advances in the art are well covered by many valuable technical papers of the year including those which are to be submitted at this Convention. There remain broad public questions regarding which engineers are peculiarly well qualified to have opinions and to influence the opinions of others and it has therefore seemed to me that I might perhaps come nearer justifying the constitutional provision by dealing with one of these.

One of the most important problems which the American people now have to solve is that of the relations between the employer and the employee classes, generally referred to as capital and labor. A large measure of our national success will depend upon this solution, and as engineers are even more directly affected by and therefore more intimately connected with industrial prosperity than are the other professions, for example, of law, medicine and theology, it is more obviously their duty to assist in the solution of the problem as much as they can. Although this subject has been voluminously discussed by numberless people for a long time, it has usually been treated from the standpoint of what ought to be— according to the views of one or the other of the interested parties. Questions of justice and injustice, legality, the so-called "rights" of labor and the protection of capital, of expediency, are brought in. There is one angle from which, so far as I know, it has not been treated, namely from the standpoint of what is, instead of what ought to be; that is to say, from the engineering standpoint,—one of fact, human nature and of economic laws as contrasted with the laws enacted by man. It therefore may be now opportune, especially to this audience, to offer a contribution from this view point, with the belief that the direction of the attention of the members of our organization to the fundamentals of so important a question may serve to clear away some of the fog which always seems to becloud the view.

To begin with, the first law of nature is self preservation. It is manifested in its highest form as patriotism, in its lowest as sordid greed. Between these two extremes appear all forms of selfishness, many of them by no means blameworthy, others under control, or not infrequently dormant, but nevertheless certain to manifest themselves when circumstances compel. For example, selfishness is the actuating motive in barter. It leads the seller to try to sell at the highest price and the buyer to try to buy at the lowest. Barter and trade are at the foundation of industry and having been always recognized as essential to prosperity have been encouraged and protected. This form of selfishness has acquired great respectability—but while the practise of matching wits in trade is supported by the people of all lands, the sanctity of contract is also fundamental, *i e.*, that form of selfishness which leads to the violation of an agreement once made is everywhere decried and condemned. It has been demonstrated that selfish human nature will assert itself and that good faith cannot be relied upon, therefore recourse has been had to another powerful trait, fear. The exercise of the police power, with its penalties for tansgression, is based on fear of consequences.

The ideal condition for barter is where both parties are absolutely free agents and neither therefore under duress. Although such a condition is seldom realized, when the duress becomes so extreme as to constitute oppression, the desperation of the oppressed may be counted upon to devise resistance. Just as surely as political oppression has throughout all history led to political revolution, so has commercial oppression caused commercial revolution. Too great power, if continued long enough, will always be abused and just as such power in government becomes tyranny, similarly too great advantage in barter begets com-

*Delivered at the 30th Annual Convention of the A. I. E. E. White Sulphur Springs, W. Va. June 29, 1920.

mercial robbery. These statements sound like platitudes and I should hesitate to repeat them were it not for the fact that they not only bear directly on the present situation between labor, capital and the public but they seem to be so frequently forgotten or ignored. Please remember that I am not blaming or praising any one. I am trying to recite cold facts and to call things by their right names.

In the time-honored barter between employer and employee, the employer formerly held the strategic position. If he refused to pay the wages demanded by any individual there was usually some one else willing to accept a lower rate and the unemployed one, not being mobile and usually having to work to live, was soon forced to yield. As business concerns grew larger this advantage naturally increased and just as naturally the employers' power was abused. By and by the resulting oppression became sufficiently acute to provoke general resistance and the labor union came into being. Workmen banded together to eliminate competition among themselves. It should be noted that the establishment of unions did not suspend the operation the law of supply and demand; rather did it allow that law freer play by counterbalancing the power of the union against the previous strategic advantage of the employer. The effect was generally beneficial because it corrected an evil, and the general public while not particularly interested looked on approvingly. But early in their history the unions made a serious although not a surprising blunder. They set up a system of contracts between employer and employee and, because they could escape doing so, provided no means by which the workmen could be penalized for violation, except by the union itself. This flagrant flouting of a fundamental did not for a time have any serious effect, but the blunder once made was never thereafter corrected and it is probable that even today it would be difficult to find a labor leader who could be made to see the seriousness of this mistake, much less to endeavor to rectify it. I pass quickly over a long period of years after the first organization of unions during which unionism had its ups and downs and came to be regarded, if not with equanimity, at least with tolerance by the employer class, and come to the recent period of the World War. Here an entirely new condition was created—an imperative demand for men came up almost over night. It simply had to be satisfied at no matter what price. At the same time not only was the supply diminished by those required for the armed forces but immigration stopped as well. The effect on the price of labor was axiomatic—it rose. The unions being the vehicles through which the demands of many classes of workmen could most readily be expressed at once became active. The law of supply and demand was fighting on their side and they made the most of it. Wages and prices rose to hitherto unheard-of figures. Labor had too much power; its demands had to be met whether or no, and of course it abused its power. Then the unions made another mistake. They credited too much of their successes to their organization and failed to appreciate the part played by the law of supply and demand, also they underestimated the power of resistance which could be engendered by oppression. In their turn they became the oppressors—insistent, arrogant. Where their principal weapon, the strike, was not effective as against the employer class in one industry, they enlisted the workmen in other industries, and who had no grievance, in sympathetic strikes. They asserted their power to dominate the public convenience, safety and health in order to coerce their opponents into submission to their will. Were it necessary I could recite many specific instances to prove this fact but I assume it to be so generally known and accepted that a recital would be superfluous. Now this is the condition to day and it is one which has caused much grave concern and has produced many strange ideas. We hear that a new order of things has come to pass; that the "rights" of labor must now be respected; that the workman will hereafter have a greater share of the products of his toil; that he must share in the management of industry and have a recognized place in government, and the like. To my mind the facts warrant none of these assumptions. There is no new order,—economic laws are the same as they always have been. They are as ruthless and as inexorable as are the laws of physics. Neither has human nature changed. The unions are in the saddle, but, to use a hunting expression, they are riding for a fall. Please let me remind you again that I am not blaming the unions, or any one else. I am trying to confine myself to statements of facts and to logical opinions based thereon according to the precept and training of the engineer. Suppose we analyze the fundamentals.

In our system of govermnment where every man can vote and have his vote counted, and with our multitude of newspapers informing everybody of what is going on, there is little chance that a condition can arise such as that of China or of Russia or even of Germany. Further while we talk a great deal of politicians and parties, we know that on any really vital question the people are going to make up their minds themselves and will elect men who will carry out the wishes of the majority. In other words the great majority rules.

The number of workmen in labor unions is variously estimated to be from ten to forty per cent of the men employed in trades where there are unions. These figures represent the extreme claims of the contending parties. We shall probably not be far wrong if we take a compromise figure of say 20 per cent. In the largest class of all, the farmer there are no unions and similarly none in many other avocations, so if we consider the total voting strength of the country, the percentage of men in unions is certainly not over

10 per cent and probably not over 5 per cent. Of this small proportion a few are the leaders, a larger number enthusiastic followers and the great majority largely governed by conditions. By that I mean they are loyal unionists when the union is succeeding but desert on small provocation when it is defeated. This is almost obviously true because the workmen are banded together to accomplish selfish purpose and no other. The individual workman cares no more for his fellow as a class than does the employer. It follows therefore that a union must continue to succeed or it will disintegrate and disappear. The history of the last thirty years has recorded many once powerful unions even the names of which are now almost forgotten. The "Knights of Labor" and "The Amalgamated Association of Iron and Steel Workers" are two examples which illustrate this point. The strength of organization contending against the mob is very great and it is probably true that so small a proportion as ten per cent or even as five, would prevail under these conditions. That in fact is the situation confronting the nation today. This small organized percentage supported by the operation of the law of supply and demand has prevailed, but looking into the future, it seems clear that there is only needed a sufficient incentive to induce the unorganized 95 per cent, or even a small part of them, to get together in opposition to the five per cent in order that the latter may be overwhelmed. This incentive has been or will be furnished by union oppression. I say "has been or will be" because the abuse of too great power always grows. Therefore if the unions shall still continue to gain their ends, even in the face of their present insolence and ruthless disregard of others, their arrogance and self confidence born of such successes, will inevitably lead them on to acts of greater and yet greater oppression until they force their opponents to combine against them for defense or even for self preservation. The moneyed class never has had, and probably never will have much sympathy or cooperation from the general public for the very obvious reason that the general public is jealous of it. Sympathy goes naturally to those who are worse off. The moneyed class being better off than the great majority therefore comes in for sympathy with a minus sign, that is, jealousy. An incentive which will induce the public to oppose the unions can therefore be sufficient only when the reason is strong enough to overcome this jealousy. That reason becomes sufficient when the need for self preservation is made clearly apparent. Already there are indications that the people will not much longer submit to domination by the unions. The Governor of Massachusetts defied them, was shortly thereafter reelected by an abnormally large majority and has now been nominated on the Republican National ticket for Vice-President which latter distinction it is safe to say he owes almost entirely to this incident. The State of Kansas has enacted a law to curb union interference with the peace and comfort of her citizens and her Governor has become a popular National figure in consequence. The temper of much of the daily press has changed, and where formerly there was much said about the so-called "living wage" and criticism of "capitalistic greed" "there now appear articles about the vicious cycle of mounting wages and costs", "loafing on the job" and the "need to teach the people thrift and economy". These and other signs are merely symptoms of the incentive to resistance that may be expected to be superinduced by oppression. The aroused public would not be just to the unions, and an attack once thoroughly launched might be expected to go further than it should. However I am not here discussing justice or how either party should behave but rather what they have done in the past and under pressure of human nature and economic laws most certainly will do in the future.

Whether or not an aroused public does curb union domination, the present high wage era will not be radically affected. That is a condition controlled, not by the unions at all, but by the law of supply and demand. Even the complete abolition of the unions while it might check further increases and perhaps bring about some recessions, and while it would reduce living costs some what by cutting out interruptions, and tend to increase production, would not itself either increase the supply of workmen available nor decrease the demand for their services. Indeed while I have discussed the fundamentals of barter between the employer and the employee and have endeavored to show the natural reactions resulting from barter with either party under duress, it is not at all certain that conditions will become so extreme as to bring about the reaction described. That is to say, instead of the abuse of power by the unions being curbed by the organized opposition of other classes of our people it may be reduced or even thwarted by the operation of the law of supply and demand. Lest I may be misunderstood I might here state that because I have been confining myself to a discussion of the relations between the employer and the employee and have had much to say about the employee's abnormally high wages, I do not want to be understood as giving that condition as the only cause of the prevailing high prices. Advantage has very generally been taken of the opportunity to increase profits by those who had wares to market, which is only another way of saying again that selfishness is a universal trait of which no class or classes has a monopoly. A bettering of conditions may be affected by a decrease in the demand for or an increase in the supply of labor. Already there is a marked reduction in the sales of certain products resulting from an unwillingness or the inability of many people to pay the exorbitant prices asked. Government re-

ports of falling exports indicate that the expected lessening of the foreign market for our high priced products is approaching and it is not at all unlikely that this may be followed by heavy increases in our imports which will displace American made goods. This result may come about both because foreign nations are getting into their stride of production again and because the high prices prevailing here have naturally created an attractive market. A combination of these and other conditions will reduce the demand for our products and consequently for the workmen to produce them. The immigration authorities of the port of New York report their facilities overtaxed to handle the large numbers coming to our shores, and say that even those numbers would be far larger if there were only more ships to carry the people who want to come. It is natural to suppose that as the heavy burdens of after-war taxation are brought home to the foreign people an increasing percentage will seek to escape them by coming here to live, and also that the gradual restoration of trans-Atlantic shipping to its normal schedules will afford the greater facilities thus demanded. This augmentation of population—largely workmen of course, will swell our supply and likewise tend to correct any shortage that may exist.

If my analysis of the facts is correct, it is clear that the present domination by organized labor is temporary and also that the era of high prices will pass. Therefore, no material permanent change in either our social order or in our industrial stucture is to be anticipated. In the contest between brains and brawn, waged since the world began, brains have always won and brains always will. Free play for the natural forces of trade may be counted upon to exercise a beneficent influence and it should be hampered and interfered with by government restrictions as little as possible. We cannot of course determine from history or from any facts at hand, how long a time it will take for conditions to become normal again but what we need now is clear thinking, courage and patience. I know that we can rely on the engineer for clear thinking and I haven't the slightest doubt about his courage, but I am not so sure about his patience. You should be leaders of thought in your several circles. You can help to allay much of the present anxiety about the so-called unrest and the apprehension as to the future; therefore I feel warranted in asking you to give your close consideration to the subject matter of what I have said this morning.

CORRESPONDENCE

TRANSMISSION OF MUSIC BY RADIO

To the Editor

In the July number of the JOURNAL under caption "The Transmission of Music by Radio" is described a recent transmission of music giving the impression that the possibility of this method resulted from research work at the Bureau of Standards, Washington, D. C. As a matter of record, perhaps the first radio telephone transmission in this country was that of music in the spring of 1907, from the old building at the corner of 39th Street and Broadway, which housed the Telharmonium apparatus. The radio music there transmitted was first "picked up" at the Brooklyn Navy Yard by Mr. George Davis, then Chief Electrician in charge of radio.

In 1909 radio music was sent out from my laboratory at 103 Park Avenue; Mme. Mazarin, of the Manhattan Opera Company singing on one occasion the "Haberana" from Carmen, to a select radio audience in Newark. A little later a temporary installation was made on the roof of the Metropolitan Opera House, and music picked up by microphones on the stage was sent out.

During the summer and fall of 1916 regular nightly "concerts" of phonograph music were maintained at the Highbridge Radio Laboratory, this music being heard at that time as far as Buffalo. Parties in New Jersey danced to this music played 35 miles away.

Since last winter radio music from Ossining has frequently been heard in Chicago and at points even farther west. From the stage of the California Theatre at San Francisco daily and nightly distribution of music from a 50-piece orchestra has been carried on for the past two months. This music has been heard in St. Paul, Minn.

LEE DEFOREST

ELECTRON TUBES AS DETECTORS

The currents which electric waves produce in radio receiving apparatus are extremely small and alternate at very high frequencies. Because of the rapid reversals and the feebleness of these currents, they cannot be detected by ordinary electric-current indicating instruments, and special apparatus must be provided for this purpose. This is usually designed to convert these currents into a form which can be detected with a sensitive galvanometer or telephone receiver.

One device for this purpose is the electron tube, sometimes called an audion, which has entirely replaced the crystal detector formerly used. There is a need for exact knowledge of the properties and behavior of electron tubes, in order to secure such designs as will work most effectively in a particular circuit. Methods of measurements have been devised and an investigation carried out at the Bureau of Standards, as a result of which the mode of action of these tubes as detectors has become more definitely known. A special form of electric measuring bridge has been constructed, by means of which the four coefficients upon which the action of the tube depends are easily measured.

Information on this and other work on electron tubes is included in a treatise on the subject which is now in preparation by the Bureau of Standards.

Sawmill Refuse, Powdered Coal, and Oil Fuels

BY DARRAH CORBET

Charles C. Moore & Co., Seattle

THE writer realizes in attempting to present any paper on as broad a subject as seems to be indicated by the one in hand that of necessity a great deal will have to be omitted and many subjects touched on but briefly which could well be analyzed to great length.

There are three fuels under consideration—saw-mill refuse, powdered coal, and oil. On the first of these fuels there is available comparatively little authentic information. On powdered coal a great deal has been written, and although this fuel has been in use for twenty years or more it is only just recently that successful installations have been made in power plants, and it is only in such installations that the writer will interest himself in this article. On oil fuel on the other hand a great deal has been written and a great many data are available. This fuel has been used for a long time and probably on account of its convenience and very extensive use in certain sections and on account of the accuracy with which determinations can be made when using this fuel, data have been compiled for operations and tests under almost every conceivable condition.

On account of the recent very rapid increase in the costs of coal and oil fuel there has been a strong tendency, particularly on the Pacific Coast, towards the use of sawmill refuse fuel. This fuel is probably available in larger quantities in this Northwestern territory than in any other part of the world at the present time and it would certainly seem that it was high time that use was made of this fuel, which for years and years has been wasted and has been a really heavy expense to the producers in ridding themselves of it.

The writer intends to analyze more particularly at this time sawmill refuse fuel and the results that have been secured with its use in such installations as are able to furnish us with data. As previously stated the available information on this subject is not very extensive and we wish you would bear this in mind and realize that later experiments and tests may indicate that results can be secured different from and far better than those referred to herein.

In the case of oil fuel, that secured from one locality does not differ very greatly from that secured from another, percentages of moisture and foreign matter vary slightly and the heat units per pound also vary a little but the general characteristics of the fuel, the method of firing it, applies equally well to one oil or another. On the other hand coal fuel is recognized as having a considerable variation, coals are graded according to fineness. They also vary materially as to the number of heat units per pound, as to the amount of foreign matter and ash present in the fuel and as to their characteristics in burning. We refer to them as anthracite, bituminous, sub-bituminous, lignite, etc. Some are coking coals, and some are not, the exact reasons for which have not been determined. In burning coal, very great care is always taken to try and design a furnace suitable for the particular fuel to be burned in the plant. It has been learned by experience that this is necessary, and desiring to secure the best possible results, operators use all information available in order to improve their operating conditions. As regards sawmill refuse fuel, however, it has in general been customary to assume that a furnace with grates and surrounding brick walls or boiler heating surface suffices to make a good combustion chamber, and although this fuel has been used for the greatest number of years, certainly there is available less information as to its use in boiler plants than for any of the other fuels referred to hereinbefore.

A description of sawmill refuse fuel is desirable, particularly for those who, from close contact with the sawmills, may not be familiar with it and it is probable that the average man does not realize what a diverse class of fuel is referred to as sawmill refuse. Sawmill refuse fuel, as it is ordinarily termed, contains wood of every kind and size, from the finest dust from sanders to chunks and blocks of wood as large as probably a twelve-inch cube.

In general it is fortunate that the fuel is delivered somewhat in these diverse dimensions, in the ordinary plant, for they unquestionably would not be able to operate satisfactorily with either of the extreme sizes alone, and it is questionable whether a very satisfactory combustion could be secured with very fine sawdust alone, particularly if it be wet, in any type of furnace and this same applies in the case of fine coal. It is unquestionable that furnaces for sawmill refuse fuel should be designed for the fuel to be handled, and in general the two important elements to be considered are the shape of the fuel and the percentage of moisture in it. More recently, particularly in order to secure additional fuel, the mills have been putting slabs through a hog, thereby securing a fuel made up of chips of various sizes but of such shape as to burn readily and such shaped fuel is highly desirable in almost every plant burning mill refuse. The chips from a hog should average bits of wood approximately the size of one's finger, but when hog knives are dull frequently very much larger pieces go through. Of course the fuel is not round but is more particularly in flat chips. Of sawdust there are various sizes, from that from sanders, gang saws, band saws, and circular saws up to that which comes from shingle machines and from box board plants where the majority of the cuts are

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with the grain of the wood resulting in sawdust which closely resembles excelsior. This latter also is a very desirable shape of fuel. From planers there are delivered shavings of various sizes and dimensions, the majority of which, however, are of a size to have an area less than that of a half dollar, and comparatively thin.

There is available as refuse from sawmills a great variety of woods. In some respects these woods are very similar but there is a great variation in some of their characteristics, particularly as regards the moisture content. The writer is giving below a list of the principal woods available in the different districts referred to and their approximate moisture content as ordinarily received as fuel from the sawmills:

CHARACTERISTICS OF PRINCIPAL SAWMILL REFUSE FUEL

Name of wood	Location	Percentage Moisture	Fuel Characteristic
Birch	Michigan	40 to 45	Fair burning
Cedar	Western Washington—Oregon and British Columbia	45 " 55	Fair
Cedar	Central California	40 " 50	"
Cypress	Florida, Texas, Mississippi	35 " 54	"
Fir	Washington —Oregon, British Columbia	35 " 45	Good
Fir	Central California	35 " 50	Poor
Hemlock	Washington, Oregon, British Columbia	40 " 50	"
Hemlock	Michigan	45 " 55	Poor burning
Maple	Michigan	40 " 45	Fair "
Pine-Cork	Eastern Washington—Idaho	35 " 45	Fair
" long-leaf	Florida and Gulf Coast	40 " 50	" burning
" Short "	" " " "	40 " 50	"
" " "	" " " "	20 " 40	"
" White	Mexico	45 " 55	"
" "	California	30 " 45	"
" Sugar	California	40 " 65	Poor
" Yellow	Central California	40 " 45	Fair
Redwood	California	45 " 50	Poor

It is interesting to note that dry non-resinous woods give off practically the same amount of heat in burning. This averages approximately 8500 B. t. u. per pound. From the above statement the reader should not be confused to the extent of assuming that the same volume of dry non-resinous woods give off the same amount of heat in burning. In order to make this perfectly clear the writer is pleased to give below a table secured from the United States Department of Agriculture Forestry Service showing the relative fuel value of non-resinous woods based on their specific gravities:

RELATIVE FUEL VALUE OF NON-RESINOUS WOODS BASED ON THEIR SPECIFIC GRAVITIES

	Specific Gravity (dry)	Relative Fuel Value per Unit Volume (dry wood)
Hickories, average	0.64	100
Oaks, average	0.58	91
Beech	0.56	89
Birch	0.55	87
Maple	0.55	87
Ash	0.52	81
Elm	0.52	81
Tamarack	0.49	76
Chestnut	0.42	65
Douglas Fir	0.42	65
Hemlock	0.39	61
Lodgepole Pine	0.37	58
White Pine	0.36	56
Redwood	0.35	55
White Fir	0.35	55
Spruces, average	0.33	52
Alpine Fir	0.31	48

The fuel value of woods varies considerably due to the amount of resin present. In general the woods ordinarily encountered in the Northwest territory do not contain large percentages of resin, however, some of them do contain certain percentages and consideration must be given to this in considering the fuel value of the refuse. Long-leaf pine encountered in Florida or the Southern Gulf Coast probably contains a larger percentage of resinous matter than any other woods in this country and the writer understands that in certain cases the resin content is as high as fifty per cent. As the calculated calorific value of resin is about two times that of wood, it is evident that the resin present has considerable influence on the heating value. Below is given a table compiled by the Forestry Service showing the relative fuel value of long-leaf pine containing different amounts of resin, and compared to hickory. In calculating the table the fuel value of resin as taken is 9400 calories per kilogram or approximately 16919 B. t. u. per pound:

APPROXIMATE RELATIVE FUEL VALUE OF LONG-LEAF PINE CONTAINING DIFFERENT AMOUNTS OF RESIN AND HICKORY

Resin Contents Per cent	Specific Gravity (dry)	Relative Fuel Value Unit Volumes of Dry Wood—Hickory 100
0	0.44	69
10	0.49	84
20	0.55	103
30	0.63	128
40	0.73	160
50	0.88	206

The other woods whose calorific value varies according to the amount of oil and resin they contain are short-leaf pine, loblolly pine, Western yellow pine, pinion pine, pitch pine, cedar, fir, juniper, cypress, etc.

It is interesting to note that non-resinous woods from an ultimate analysis are shown to contain about 50 per cent of carbon and the other parts principally hydrogen and oxygen in the proportions which burn to water. An analysis of woods most generally referred to is as follows:

ULTIMATE ANALYSIS OF WOOD

	Per cent Carbon	Per cent Hydrogen	Per cent Oxygen	Per cent Nitrogen	Per cent Ash	B. T. U. per lb.
Ash.....	49.18	6.27	43.91	0.07	0.57	-8,480
Beech...	49.06	6.11	44.17	0.09	0.57	8,591
Elm....	48.89	6.20	44.25	0.16	0.50	8,510
Oak.....	50.16	6.02	43.36	0.09	0.37	8,316
Fir......	50.36	5.92	43.39	0.05	0.28	9,063
Pine ...	50.31	6.20	43.08	0.04	0.37	9,153

There have been comparatively few ultimate analysis made of sawmill refuse fuels but the writer is pleased to include a few reports of analyses made which are particularly interesting because they are so scarce, though in general it will be noticed that they do not vary much from the analyses given hereinbefore. It is very difficult to make satisfactory ultimate analyses of wood samples and this is probably the reason why more have not been made.

ANALYSIS OF HOG FUEL SAMPLES

Sample No.	Per-cent mois-ture	Per-cent vola-tile	Per-cent fixed carbon	Per-cent ash	B. T. U. Per pound dry fuel	Per-cent carbon	Per-cent hy-drogen	Per-cent oxygen
1	62.85	81.70	18.06	.24	9010	.....	....	.....
2	47.9	39.7	11.7	0.7	8970	.....	....	.....
3	27.6	56.4	14.9	1.1	8800	.....	....	.....
4	36.1	49.1	14.0	0.8	8740	.....	....	.....
5	34.17	....	.....	0.78	8342	45.61	6.14	47.05
6	21.94	....	.....	0.05	8586	47.03	6.55	46.36
7	42.26	....	.....	0.44	8682	.....	....	.....
8	48.83	....	.....	0.58	8193	.....	....	.....
9	40.28	....	.....	0.35	8039	46.75	5.81	46.84

1. Mixed refuse from Yosemite Lumber Co.
2. Average mixed fuel, Portland territory
3. Average fuel from manufacturing plant (using kiln dried material, Portland territory)
4. Average mixed fuel from lumber mill, Portland territory
5. Sawdust from first cut average fir log, Grays Harbor territory
6. Sawdust from heart clear fir logs, Grays Harbor territory
7. Mixed fuel from sawmill, Grays Harbor territory
8. Mixed Spruce refuse, Grays Harbor Territory.
9. Sawdust from clear spruce logs, Grays Harbor territory.

Sawmill refuse as we ordinarily secure it is seldom if ever segregated so as to contain but one class of fuel and particularly is this the case in the Northwest territory where the fuels are a mixture of various kinds of woods, the mills themselves cutting various kinds of logs, more or less as they happen to be delivered. The moisture content of the refuse is also a very variable item due to the fact that the refuse may come from not only the different kinds of woods but from different parts of the manufacturing plant where they may be handling very wet or kiln dried lumber. Then in addition a very large amount of moisture is added to the sawdust from some of the saws, particularly large band saws where water is kept running on the saw in order to keep it cool and assist in the cutting.

SAWMILL REFUSE FUELS

Source	Kind of fuel	Moisture	B. T. U. dry fuel
Eureka, Calif.	Redwood sawdust and hogged fuel..............	50.58	8887
" "	Redwood sawdust and hogged fuel..............	55.38	9192
Samoa, Calif.	Redwood sawdust from sinker logs..............	66.66	8961
" "	Redwood sawdust and shavings (part dry)	41.22	9088
" "	Redwood sawdust and shavings (part dry).......	43.18	8857
Scotia, "	Redwood sawdust and shavings................	4940	9176
" "	Redwood sawdust and shavings................	48.73	9231
Merced Falls, Calif.	White pine, cedar mixed fuel.	62.85	9010
" " "	Cedar sawdust.............	58.30	9285
" " "	White Pine sawdust.........	61.02	8898
" " "	" " Cedar mixed fuel	57.60	8753
Portland, Oregon	Fir, Hemlock mixed fuel.....	47.90	8970
" "	" " " " (dry)	27.60	8800
" "	" " " " (part dry)...................	36.10	8740
Bellingham, Wash.	Fir, Hemlock mixed fuel....	41.95	8901
" "	" " " "	42.67	8865
" "	" " " "	41.55	9078
Tacoma, "	" " " "	38.50	8953
" "	" " hogged fuel....	41.50	8979
" "	" " shavings.......	34.00	8474
Aberdeen, "	" sawdust first cut " " average dry.	34.17	8342
" "	" " from center average dry.............	21.94	8586
" "	Fir Hogged slabs and mill waste...............	42.26	8682
" "	Spruce Hogged slabs and mill waste...............	48.83	8193
" "	Spruce sawdust from clear wood...................	40.28	8039
Everett, "	Fir and Hemlock mixed full .	41.40	8642
" "	" " " " " .	39.09	8733

Quite a good many analyses have been made of the heat content of various samples of sawmill refuse fuel and the writer is pleased to give herewith a table showing some of these, with a memoranda indicating the source of the fuel as this is of the greatest interest and value. A few of these analyses were made for the Portland Railway and Light & Power Company by the Experimental Engineering Department of the Oregon Agricultural College, and by the Oregon Independent Testing Laboratory, Portland, Oregon, the rest of the analyses having in general been made by the Babcock & Wilcox Company.

The woods particularly considered in this article are those encountered on the Pacific Coast. The total amount of fuel available in this district is a matter very difficult of analysis but tests have seemed to indicate that approximately a total of one-half a unit of fuel is available per thousand board feet cut by a sawmill and as the total cut of the Pacific Coast, including Nevada, California, Oregon, Washington, and Idaho, during 1919 was approximately 9,250,-

000,000 board feet there should be available approximately 4,625,000,000 of units of mill refuse fuel per year. Certainly a considerable portion of this fuel is and will be used as slab wood and mill wood in the home. At present a larger amount of wood is used in this manner than is used in the industries outside of the sawmills themselves whose consumption of fuel it is difficult to judge.

The writer has referred to a unit of fuel and as the definition of a unit of fuel is frequently asked, an explanation at this time is in order. The writer believes that the Grays Harbor Railway & Light Company Plant at Aberdeen, Washington, was the first electrical generating station of material size designed to use sawmill refuse fuel. When the people operating the plant went out into the market to buy fuel it became necessary for them to arrive at some unit as the basis of a measure of fuel. Some experiments were made by putting a cord of slab wood through a hog and measuring the resulting fuel and although this seemed to indicate that approximately 177 cubic feet of hog fuel was the equivalent of a cord of wood before being put through the hog, there was established, the writer believes, by Mr. E. A. Bradner, the standard of 200 cubic feet as the measure of refuse and this was designated as a unit.

It is probably unfortunate that the unit has been established as a measure of sawmill refuse fuel as it is certainly not a good indication of the available heat units in such fuel. There is a very considerable variation in the weight of a unit of fuel due partly to the moisture content and partly to the settling of the fuel if it is allowed to stand for any length of time, particularly when subject to a superimposed load as is the case in high piles. No very accurate information is available to show just how much the fuel may settle but it is probable that there is a variation of a quarter or a third as a maximum from very loose fuel to that tightly compacted. Those who have had experience in piling sawmill refuse fuel in high piles or storing same in large fuel houses, realize how the fuel is compacted when they endeavor to remove the same, finding it so hard that it is frequently necessary to chop it out in order to remove it from the pile. It is practically impossible to remove it from the bottom of the pile while the load is carried overhead and it is necessary to remove the fuel by starting at the top and working down.

Certainly one of the reasons why mill refuse fuel has not been more extensively used is the difficulty of transporting and storing the same. The fuel is very bulky and on account of its characteristics is rather difficult to handle. It has only been very recently that this class of fuel has been transported any material distance and even now it is seldom that the fuel is moved more than a hundred miles on account of the high cost of transportation. The methods in use at the present time to transport the fuel consist in the main of barges, railway cars with special bodies and trucks. The latter are of course used only for comparatively short hauls. The difficulty is practically always in loading enough fuel into the transporting vehicle to give it an economical load. This condition is most nearly reached in the case of barges, and it is unquestionable that this is at the present time the best means of transporting the fuel, but of course the supply available where it can be loaded conveniently into barges and transported to the consuming plant is limited.

In general it is found that refuse fuel can be loaded quite conveniently if it is loaded directly from the mill and not run into previous storage. As long as the fuel is kept moving it is comparatively easy to handle, but when it is put into large piles or large storage bins then the question of handling it becomes a serious problem.

In the sawmills this class of material has in a great majority of cases been handled over chain conveyers; these are of various types but the principle is to scrape the fuel along a smooth trough from one point to another. The other principal means of moving it is by blowing the lighter fuels, such as planing mill shavings, etc., with fans and a strong blast of air from one point to another where the fuel is separated out from the air and deposited into bins or other conveyers. The sawmill men, having had a great deal of experience in handling this class of fuel, have, as is natural, hit upon a satisfactory means of moving it, and the writer knows of no more universally satisfactory means than the two referred to above; however, when large quantities of fuel have to be handled conveyers of this type become extremely heavy, expensive and hard to operate and in such installations it has been found that belt conveyers work admirably.

There are limitations to the use of belt conveyers. It is the writer's opinion that they should not be used with wide boards, and narrow belts are unsatisfactory because so much of the fuel is lost over the side. Then again it is not very satisfactory to unload the belt at more than one point unless a tripper is used, which is a piece of apparatus so expensive that its use is not warranted in small plants. There is a question as to whether belt conveyers should be troughed or flat, the writer prefers and sees no serious objection to the troughed belt and he would recommend it.

There is no use in this article to describe conveyers, particularly chain conveyers, which are of numerous designs and are in general well-known. The type of conveyer for any particular plant depends upon the fuel to be handled, and the service required. The writer has already spoken briefly of the storing of this class of fuel and has stated that it is easy to store the fuel but very difficult to get the fuel out of storage. In sawmill plants it has been the custom to store the fuel in fuel houses at which point there is collected all of the various kinds of refuse that come from the mill,

excepting of course the larger sticks and pieces which are usually burned up in a refuse burner. Such storing of the fuel is quite satisfactory where large quantities do not have to be handled but experience has indicated that a great deal of difficulty is experienced in removing this fuel from large fuel storage bins. In such containers when the fuel is allowed to stand for a time it settles down into a very compact mass and some mechanical means should always be had for loosening the fuel up on the surface and gradually working it down from the top.

On account of the difficulty of storing the fuel in houses large quantities have recently been stored in the open and later reclaimed for fuel use. The two largest storages at present consist of the one at Station "L" of the Portland Railway Light and Power Company and at the plant of the Northwestern Electric Company, both at Portland, Oregon. It is really not very expensive to store fuel in this manner if ground space is not too valuable. The fuel is moved with specially designed rakes and in a well designed installation but little labor is necessary.

There has been a great deal of discussion as to the possible fire hazard in storing large quantities of this fuel either in fuel houses or out in the open. Some years ago, the writer being particularly interested in the subject, investigations were made and the Forestry Bureau was appealed to for information as well as the fire insurance companies. No record was had of any fire having started in a fuel house or in a pile of fuel due to spontaneous combustion and but few fires have occurred which have destroyed fuel houses. When piled up in a large mass this fuel is very hard to burn and can be burned from the surface only, so that severe conflagrations are not at all likely, as a matter of fact it is very difficult to get the fuel to burn when in large piles even in furnaces. It is the writer's belief that there is very little fire hazard indeed from storing this fuel as it is ordinarily received. Very dry sawdust and shavings from kiln dried lumber might cause difficulty if they alone were stored in large quantities but this condition is practically never encountered.

There is unquestionably some depreciation in the fuel value of mill refuse when stored, particularly in the open for a material length of time. The writer is very much of the opinion that this amounts to but little under ordinary circumstances. He has heard of one or two instances where fuel of this kind has been recovered after years of lying out in the open and with its use satisfactory steaming of the boilers was secured. At least one sample of fuel having been stored eight months in the open was analyzed by the Portland Railway Light & Power Company which seemed to indicate that there was a large increase in the moisture content of the fuel, some slight increase in the amount of ash and a little falling off in the B. t. u. per pound dry fuel, doubtless due to the ash present. The writer is not certain as to just how this sample was selected but it is certainly not always the case that in storing fuel the moisture content is increased as certainly in many cases the fuel is dried out somewhat as lumber is air dried. In drying out in this manner a certain portion of the water is quickly given off, particularly if atmospheric conditions are at all favorable. The evaporation then slows up very suddenly and a considerable amount of moisture is always retained.

The type of furnace for sawmill refuse fuel is a matter that should receive most careful attention. The writer has tried to explain hereinbefore that sawmill refuse fuel is of very diverse types and a consideration of the particular fuel to be burned should determine in a large measure the design of the furnace.

There are, however, a few fundamental features in the design of the furnace which from analyses and from experience evidently are correct. Although it is quite probable that as good or possibly better efficiencies could be secured with hand firing, the great majority of installations feed the fuel to the furnace in a more or less continuous stream, the fuel being delivered through a hole in the top of the furnace to pile up in a cone on the grates. This method of firing is much the most simple and economical from a labor standpoint, one man being able to take care of several thousand horse power of boilers in a properly designed plant.

Considering fuel to be delivered to the furnace in continuous manner referred to above, then one can readily see that in order to expose the greatest possible amount of surface of the cone for burning and yet to prevent excessive infiltration of air through the grates each fuel pile should cover practically a square section of grate. Experience has indicated also that this is essential for the best operating conditions. If additional grate surface is desired in front of a boiler then the furnace can be so designed that there will be two fuel piles per furnace, piles being arranged in tandem, the grates then being pratically twice as long as they are wide.

The writer is of the opinion that a furnace approximately six feet wide is ideal but in many installations it is impossible to secure ideal conditions and therefore furnaces have to be designed, many of them operating entirely satisfactorily, which vary widely from the width specified above. It is very probable that a reduction in the width of the furnace is more serious than an increase in the width of the furnace from the figure referred to and as a matter of fact it is quite possible, and many satisfactory installations have been made, where furnaces are as much as 12 feet wide but in such cases the grates are covered by at least two fuel holes across the width of the furnace. There are some structural difficulties in making a furnace wide, as that of the support of the fire brick arch, which should be over the top of the grates.

Experience has indicated that with any type of

fuel furnace temperatures can be varied by changing the area through the throat of the furnace. Any tendency to bottle up the furnace results in a material increase in furnace temperatures. High temperatures are desirable for burning ordinary sawmill refuse and this bottling effect can and is secured most advantageously by running the bridge wall up to such a point as will give the desired temperatures without interfering materially with the draft. The furnace should be surrounded on the top and sides with incandescent fire brick. The reflected heat aids in the combustion of the fuel and the distillation of the moisture present.

The area through the throat of the furnace referred to above is a variable quantity and shouldbe figured out carefully for the installation. The writer cannot give a detailed analysis of this particular feature but in general will state that the area through the throat of the furnace should be from 6 to 14 square inches per rated boiler horse power, depending upon fuel conditions, design of furnace, the rating which is to be expected, and the available draft.

The question of the proper admission of air to the furnace is a matter of considerable importance. As the combustion is mostly on the surface of the cones of fuel the air should be available at these points. It is undesirable to have excess air with this class of fuel as with any other. In some installations it has been found desirable to keep the fuel holes at the top of the furnace open for the admission of air and in other installations far better results are secured by closing these up by one means or another. As with almost every class of fuel slight adjustments are necessary after the plant is put into operation; the writer believes that this particular point of the admission of air through the fuel holes is one that should receive special consideration at that time and there is no very good way of telling before hand just what to expect.

The analyses of this class of fuel that have been made indicate that it contains a very large percentage of volatile. It can readily be understood that this will be quickly distilled off in a hot furnace and in addition much of the finer fuel is quickly carried with the force of the draft out of the furnace. These conditions make it highly desirable that the installation be provided with a combustion space back of the furnace and before the heating surface of the boiler is reached, in order that this unconsumed fuel can have an opportunity to burn before it reaches the heating surface of the boiler. In this combustion space there should be tuyeres and a door or damper to control the admission of air to them. In this manner supplementary air is added at this point and combustion conditions are materially improved. In general the most convenient place for the admission of this secondary air for combustion is through the bridge wall. Experiments have indicated that the most satisfactory place for admitting the air is either on the top of the bridge wall or on the back face of it. On the top of the bridge wall the air can be admitted through grate bars and on the back face of the bridge wall through openings made by leaving out a brick now and then. The difficulty with the opening on the top of the bridge wall is that it may become clogged with soot or ash and it permits this matter to sift down into the space below.

Under any circumstances, for the most efficient conditions, the arch of the furnace should extend beyond the point where the supplementary air is admitted as this arrangement brings the gases and the air most intimately in contact with each other.

The height of the arch above the grate is a factor depending upon the width of the furnace and the kind of fuel to be handled. The height of the arch determines in a great measure how hot the arch will be. Experiments have indicated that a change in the height of the arch of a foot or even less will change the temperature of the arch so much that the effect upon combustion is very marked. In general the arch is approximately five to seven feet above the surface of the grates. In a wide furnace it will, of course, be necessary to have two fuel holes across the width of the furnace in order to cover the grates from this height. The crown of the arch is a matter for an engineering design and cannot be covered at this time.

There are as many different designs of grates for sawmill refuse as there are colors in the rainbow. It is the writer's opinion that the simpler grates are much the best, either the straight bar or the herring bone. It is desirable to secure a grate with as large a percentage of air space as possible and yet have the bar strong enough to stand up under the rather severe conditions encountered with this fuel. The writer believes that the smaller bars are preferable due to the fact that in overheating they will not warp so far out of line as a longer bar and it is less expensive to replace them. The width of air opening in the grate is very important and depends upon the class of fuel to be handled. Where there is a great deal of fine sawdust of course the width of air space should be less. With coarser fuels the width can be increased. It seems that practically always there is a certain amount of fuel that falls through the grates and this should be prevented as far as possible. Experience has seemed to indicate that the width of the air space should not be more than one-half in. and in a great majority of cases less than this. The writer has never seen any experiments made with sawmill refuse fuel on shaking grates but on account of the very large percentage of air space (35 per cent or more) which can be secured with this type of grate and with an air opening not to exceed one quarter in. we believe that this grate in a properly designed installation would readily pay for itself. It would be particularly easy to keep such a grate clean. Ordinarily there is a certain amount of dirt fed into the furnace with sawmill refuse which clings to the bark of trees, etc., which collects

on the grate surface and periodically has to be removed.

In the majority of plants the ash pit below the grate is comparatively shallow, and the fuel which sifts through the grates, on account of the high temperature, readily burns and great difficulty is experienced in making grate bars and bearers stand up under these severe conditions. Practically all installations are provided with some means or other for flooding the ash pit or quenching fire in the ash pit with a hose or other means of that kind. Water in the ash pits unquestionably helps to keep the grates cool and adds to their life.

There are two schemes which the writer would like to recommend as offering a better solution of this difficulty, they are not original but are seldom used—one is to have a means of washing the cinder from the ash pit in a trough either carrying running water or provided with a means of turning water into it for flushing purposes and the other is to make the installation with a considerable distance between the grates and the bottom of the ash pit so that the grates will be kept cool. In practically every installation either one or the other or both of these schemes would be well worth the investment.

Experience with sawmill refuse fuel has seemed to indicate that logs which are transported in salt water pick up an amount of salts which makes the fuel from such logs harder on brick work in furnace settings. It seems quite probable that sawmill refuse under any circumstances contains certain chemical elements which make the action on brick work different from that of other class of fuel. Where one particular brand of brick would work out with oil it might not do so well with mill refuse. The writer mentions these items at this time due to the fact that we have not on the Pacific Coast as good quality of fire brick as can be secured in the Eastern states, and we always experience more or less difficulty here with our refractories. Experience is the best guide as to the type of brick to be used. In laying up a furnace for this class of fuel, as for any other, an item that has the greatest bearing upon the stability of the installation is the workmanship and the writer would like to see better brick work jobs than we are accustomed to getting in this territory. Where fire brick are laid close together and fitted with care the flames do not have much opportunity to get between the fire brick, but a well laid up job with mediocre brick will probably out-last a poor installation of good brick.

The writer has assumed the average ultimate analysis of fir wood as follows:

C	50.36
H_2	5.92
O_2	43.39
N	0.05
Ash	0.28

and from this analysis has figured the amount of air theoretically required for combustion; the total weight of the products of combustion with various percentages of excess air; the percentage by weight of the various products of combustion with different percentages excess air; and the percentage by volume of the different products of combustion with varying percentages excess air. The table of these values is given herein and from these results has been plotted a curve which indicates for the analyses as assumed, complete information within the range covered.

COMBUSTION OF WOOD

	Weight per pound wood pounds	Required pounds		Products of combustion pounds			
		O_2	Air	CO_2	O_2	N_2	H_2O
C_2	.5036	0.343	5.802	1.847	....	4.459	....
H_2	.0592	.474	2.048	....	....	1.574	.533
O_2	.4339	....	....	....	.434	....	....
N_2	.0005	....	....	....	....	0.001	....
Ash	.0028	....	....	....	....	....	....
		1.817	7.850	1.847	.434	6.034	.533
		.434	1.875	....	.434	1.441	....
		1.383	5.975	1.847	.000	4.593	.533

	Weight products combustion			Varying amounts excess air pounds		
	0%	20%	40%	60%	80%	100%
CO_2	1.847	1.847	1.847	1.847	1.847	1.847
O_2	.000	.277	.553	.830	1.107	1.383
N_2	4.593	5.511	6.430	7.348	8.266	9.185
H_2O	.533	.533	.533	.533	.533	.533
	6.973	8.168	9.363	10.558	11.753	12.948

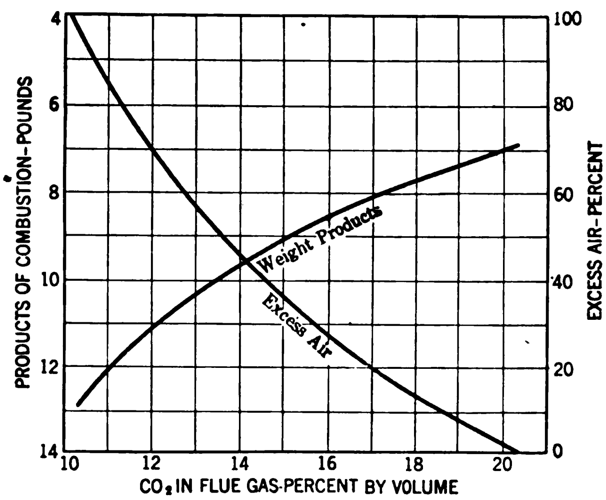
	Per cent by weight dry products varying amounts excess air					
	0%	20%	40%	60%	80%	100%
CO_2	28.68	24.19	20.92	18.42	16.46	14.88
O_2	0.00	3.63	6.26	8.28	9.87	11.14
N_2	71.32	72.18	72.82	73.30	73.67	73.98
	100.00	100.00	100.00	100.00	100.00	100.00

	Dry products per cent by volume varying amounts excess air					
	0%	20%	40%	60%	80%	100%
CO_2	20.37	16.96	14.53	12.71	11.29	10.16
O_2	0.00	3.50	5.98	7.85	9.31	10.46
N_2	79.63	79.54	79.49	79.44	79.40	79.38
	100.00	100.00	100.00	100.00	100.00	100.00

Molecular weights
O_2 = 16
N_2 = 14
CO_2 = 22

It is probable that the average analysis of sawmill refuse fuel on the Pacific Coast does not vary much from the wood analysis which has been used and it is probable that the results indicated are approximately correct for average conditions. Where analyses of flue gases can be made, comparison with this curve will give

an approximate indication of the combustion which is being secured.



It has been customary and seems to be quite satisfactory to figure stack capacities for sawmill refuse fuel on the same basis that we figure stacks for coal fuel. We can probably figure a little less stack area for sawmill refuse fuel than is figured for the standard tables of stack sizes for coal fuel. However, sufficient information has not been secured as yet so that a definite figure can be given. On the other hand with the average installation the owner is always desirous of getting large overload capacities out of his installation and to assist in this it is desirable to have tall chimneys. When one realizes that the capacity of an installation is dependent in a large measure upon the stack capacity it is readily realized that a little bit of additional money spent for a larger chimney is well invested.

In the average sawmill plant at least one or more boilers are shut down over the week end for washing out. Where steel stacks are used there is a distinct advantage of having one stack for a battery of two boilers, due in large measure to the fact that with such an installation it is always possible to keep one boiler of the battery in operation over the week end and keep the stack hot and prevent in a certain measure the corroding action which seems to be quite marked in steel stacks where sawmill refuse is used.

It is unfortunate that complete information from various sources is not available to indicate efficiencies of boilers and furnaces when using sawmill refuse fuel. We believe that the most complete tests that have been made so far have been in the plant of the Portland Railway Light & Power Company, Portland, Oregon. The writer is indebted to the courtesies of the management of this concern and to the personal assistance of Mr. H. S. Bastian, Assistant Engineer, for the very complete set of tests, reports of which follow. In giving the results as indicated by these tests, the writer wishes to call attention to the fact that the tests were made to try to provide the best type of furnace construction for the boilers at the plant. This means that they were not entirely at liberty to change the furnace design in order to secure the best possible arrangement but had to be limited largely with space available.

These tests are particularly interesting in view of the fact that very complete analyses of fuel were made from liberal samples taken during each test and all measurements were carefully taken in order to assure accurate results being secured.

It might be interesting to indicate briefly the general changes in furnace design that were made at the time the tests given in the following Table were run.

Test No. 1 was made with the boiler and furnace as found.

Test No. 2 was made with the same boiler and furnace as Test No. 1. but here hand firing was resorted to in an endeavor to show that by so doing better results could be secured from an economical standpoint than by firing through fuel-holes as was done in the first test.

In test No. 5 the same general furnace arrangement was used as in the two previous tests but a single fuel hole was used instead of two in parallel.

Test No. 6 was made on a Babcock & Wilcox Cross Drum boiler with a Riley stoker. Three feed chutes fed supplementary fuel through the front of the furnace.

Before Test No. 7 the bridge wall construction was changed and a curtain wall or hanging arch was provided almost directly above the bridge wall. There was a marked decrease in the amount of cinders discharged from the boiler during the test.

Test No. 8 was run with the general construction of furnace as in Test No. 7 except that four fuel holes were used to feed the furnace rather than one. Before this test the grate area was reduced from that in previous test by taking out some of the grates at the back of the furnace. During this test but two of the front firing holes were used.

In Test No. 10 especially dry fuel was used. The general furnace arrangement was as in previous test.

Test No. 12 was made on boiler No. 6 at Station L of the Portland Railway Light & Power Company plant. The grates were eight feet long. The front portion of the grates being about 6 feet 5 inches below the crown of the arch and in the rear about 7 ft. 10 in. The grates were therefore considerably lower, approximately 1 ft. 1½ in., than the grates in boiler No. 3.

In Test No. 13 boiler No. 7 at Station L was used. Grates were 7 ft. 2 in. long by 12 ft. 2 in. wide. Two fuel holes covered the width of the grates. Secondary air for combustion was admitted through grates placed at the top of the hollow bridge wall.

The writer wishes to call attention to the fact that efficiencies given in report of tests, based upon available heat in fuel are determined from the total heat per pound dry fuel by calculating the available heat per pound of fuel, assuming 600 degrees stack temperatures and 60 degrees temperature in fuel as fired.

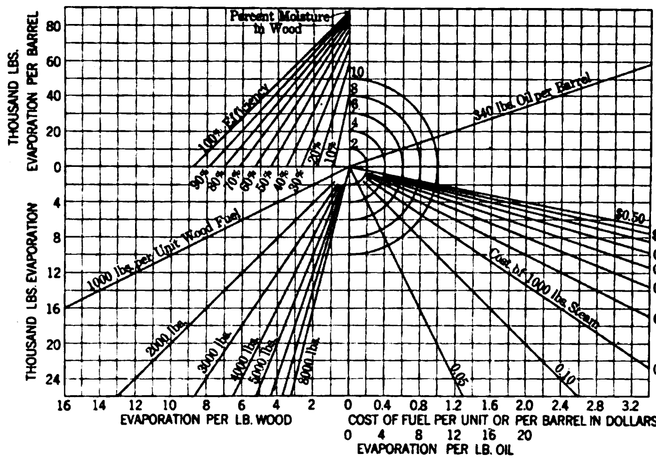
In addition to the above tests the writer is permitted to publish some tests made by the Babcock & Wilcox Company at the C. A. Smith Lumber Company plant, Marshfield, Oregon. During these tests as during the majority of tests with sawmill refuse fuels, no effort was made to determine the efficiency of combustion of the fuel and absorption of heat by boiler. The effort was to secure good combustion and determine the capacity at which the boilers were operating with the fuel available. These tests were made on Stirling boilers provided with extension furnaces or what is commonly termed the Dutch Oven setting, and each furnace was provided with two fuel holes placed in tandem in order to cover the grate area. Each boiler had two furnaces and each furnace was approximately five feet wide. The tests indicate very satisfactory combustion conditions when one notes the capacity secured from the boilers.

A great many tests have been made by the Babcock and Wilcox Company in order to determine the best possible furnace arrangement for various classes of sawmill refuse fuels and to determine the capacities that could be secured with boilers with these different fuels. As most of these tests were made in sawmill plants where fuel was of no particular value, economic results were not determined. It would, therefore, be of no particular value to repeat at length such tests at this time as they do not indicate results materially different from those already given.

It will be noted that considerable information in reference to the use of sawmill refuse fuel is yet to be secured. It would seem that we had not reached efficiencies as high as are possible, but as it is very expensive to make accurate tests, it is probable that little testing work will be done until such time as extensive purchasing of this class of fuel may make it necessary to secure more complete data.

The majority of the power plants on the Pacific Coast at the present time are using oil fuel and in order to indicate the comparative results that might be expected with sawmill refuse and oil fuel the writer has made up a set of curves for this purpose. On the sheet is indicated the assumptions that have been made and as the B. t. u. value of dry wood is quite uniform it is probable that the assumptions are not greatly in variance with the average conditions.

It is to be noted that the evaporation per pound of wood as shown by the curves is based upon the available heat in the wood as calculated. There are various ways of stating efficiencies and this particular matter should not be confused. Efficiencies can be stated on the basis of the total heat per pound of fuel as determined by a calorimeter; based upon the total heat of a pound of dry wood as determined by a calorimeter; based upon a pound of combustible; based upon the available heat as shown by a calorimeter or based upon available heat as calculated from the total heat of a pound of dry wood. This latter method is quite satisfactory and we believe applicable in the majority of cases, as was the case in the tests of the Portland Railway Light and Power Company.



Wood and Oil Fuel—Curve of Comparative Values
Assumptions: 8500 B. t. u. per lb. dry wood
200 cu. ft. = 1 unit
550° Stack temp.
60° Wood fuel temp.
Evaporations from and at 212 deg. fahr.

As an explanation of the use of the curve we can assume the following conditions and follow through a determination. Oil $1.00 a barrel, 12 lb. evaporation per pound of oil. Sawmill refuse fuel containing 45 per cent moisture, weighing 20 lb. per cubic foot efficiency 60 per cent. The problem is to determine what can be paid for sawmill refuse fuel per unit to equal the fuel value of oil at the price stated.

Starting with the value of 12 lb. of evaporation per pound of oil, directly above this at the point of intersection with the line indicating the pound of oil per barrel we note that on the left the total evaporation per barrel of oil is 4080 pounds. Transferring this below the line as indicated by the semicircle and carrying 4080 lb. evaporation across to the right we note that under the figure $1.00 per barrel, the cost of one thousand pounds of steam is about twenty-four and one-half cents.

Starting again with 45 per cent moisture in the sawmill fuel and going to the left to the point of intersection of 60 per cent efficiency we note that the evaporation per pound of wood is approximately 2.3 lb. water, or with 4000 lb. per unit this is equivalent to about 9200 lb. of water per unit of fuel. Carrying this to the right to the point of intersection with the line indicating cost of steam twenty-four and one-half cents per thousand pounds, we note $2.25 as the equivalent cost of a unit of fuel.

On the same basis if oil cost $2.00 a barrel the equivalent cost of sawmill refuse would be twice the above or $4.50 a unit. In this manner a ready reference is secured and the curve can probably be read far more accurately than will be the assumptions made.

There has not been a very extensive use of sawmill-refuse fuel in power plants, up to the present time, due

TEST OF BOILERS USING SAWMILL REFUSE FUEL
PORTLAND RAILWAY LIGHT & POWER CO.

		Test No. 1	Test No. 2	Test No. 5	Test No. 6	Test No. 7	Test No. 8	Test No. 9	Test No. 10	Test No. 12	Test No. 13
DIMENSIONS											
(1) Boiler on test		No. 3	No. 3	No. 3		No. 3	No. 3	No. 3	No. 3	No. 6	No. 7
(2) Kind of boiler		B. & W. Extended	B. & W. Extended	B. & W. Extended	B. & W. Riley	B. & W. Extended	B. & W. Extended	B. & W. Extended	B. & W. Extended	B. & W. Extended	B. & W. Extended
(3) Kind of furnace		Dutch Oven	Dutch Oven	Dutch Oven	Stoker	Dutch Oven	Dutch Oven	Dutch Oven	Dutch Oven	Dutch Oven	Dutch Oven
(4) Grate surface	Sq. Ft.	121.8	81.6	105.8	114.5	130.8	130.8	87.2	87.2	100	87.2
(5) Water heating surface	"	4399	4399	4399	4440	4399	4399	4399	4399	4399	4399
(6) Superheater heating surface	"	....	....	....	....	855	....	....	....	....	....
(7) Total Heating surface	"	4399	4399	4399	5,295	4399	4399	4399	4399	4399	4399
(a) Ratio of water heating surface to grate surface		36.1 to 1	53.9 to 1	41.6 to 1	38.8 to 1	33.6 to 1	33.6 to 1	50.5 to 1	50.5 to 1	44 to 1	50.5 to 1
(b) Ratio of total heating surface to grate surface		36.1 to 1	53.9 to 1	41.6 to 1	46.2 to 1	33.6 to 1	33.6 to 1	50.5 to 1	50.5 to 1	44 to 1	50.5 to 1
(c) Volume of combustion space between grate and heading surface	Cu. Ft.	1150	1150	1150	916	1150	1150	1150	1150	1200	1150
(d) Distance from center of grate to nearest heating surface	Ft.	9.5	10	9.5	8.0	9.5	9.5	10	10	10.5	11
DATE, DURATION, ETC.:											
(8) Date		2—4—20	2—10—20	2—20—20	3—12—20	3—16—20	3—20—20	4—1—20	4—5—20	4—19—20	5—6—20
(9) Duration	Hours	10	8	8	6	6	7	7	7½	6	5
(10) Kind and size of fuel		Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel	Hog Fuel
AVERAGE PRESURES, TEMPERATURES, ETC.											
(11) Steam Pressure by Gauge	Lb.	171	160	162	187	160	174.5	170	173	176	179
(a) Barometric pressure	Inches	30.3	30.3	29.8	30.24	29.8	29.6	29.9	30.17	29.9	30.2
(12) Temperature of steam	Deg.	372	361	368	572	369	376	373	378	375	....
(a) Normal temperature of saturated steam	"	375.5	370.8	371.5	383.0	370.8	377.2	375.4	376.6	378	....
(13) Temperature of feed water entering boiler (Economizer not working during tests)	"	84.4	77.5	86.5	74.3	65.8	68	84.9	84.9	72.5	84.70
(14) Temperature of escaping gases leaving boiler	"	610	600	560	670	520	570	520	....	460	609
(15) Force of draft in inches of water											
(a) Draft in main flue near boiler	Inches	0.444	0.27	0.43	0.71	0.48	0.48	0.50	0.40	0.36	0.51
(a) " " 1st pass	"	0.259	0.14	0.29	0.37	0.36	0.31	0.32	0.21	0.19	0.21
(c) " " ash pit, right	"	0.013	0.016	0.005	....	0.005	0.022	0.01	0.007	0.00	0.014
(d) " " " " left	"	0.0095	0.0065	0.004	....	0.004	0.024	0.007	0.018	0.005	0.010
(e) " " bridge wall air duct	"	....	....	....	......	0.25	......	......	......	......	......
(16) State of Weather		Clear	Clear	P. M. Clear	Rain	Cloudy	Cloudy	Rain	Cloudy	P. M. Cloudy	Clear
(a) Temperature of external air	Deg.	42	48	52	52	49	60	42	56	48	72
(b) " " air entering ash pit	"	65	59	57.5	68	66	65	65	64	60	77
(c) Relative humidity of air entering ash pit	%	65	55	55	85	35	55	85	57	60	35
QUALITY OF STEAM											
(17) Percentage of moisture in steam	%	2.5	1.9	2.0	....	1.34	0.9	1.06	Superheat 1.4	1.62	1.5
(18) Factor of correction for quality of steam		0.982	0.981	0.98	....	0.987	0.991	0.989	1.00	0.984	0.985
TOTAL QUANTITIES											
(19) Total weight of fuel as fired	Lb.	96,011	45,071	70,895	49,961	51,693	69,620	66,174	80.939	44,441	67,480
(20) Percentage of moisture in fuel as fired	%	50.1	49.8	41.6	35.2	35.7	44.06	46.6	34.6	47	56.8
(21) Total weight of dry fuel fired (Item 19 x (1—Item 20)	Lbs.	47,909	22,625	41,403	32,375	33,839	38,945	35,337	52,934	23.554	35,900
(22) Ash, clinkers & refuse, (dry)											
(a) Withdrawn from furnace & ash pit (no account taken of ashes, cinders, etc. carried away in flue gases.	Lbs.	207	129	224	1589	147	136	140	248	161	218

(23) Total combustible burned (Item 21—Item 22)	"	47,702	22,496	41,179	30,786	38,192	38,809	35,197	52,686	23,393	35,682
(24) Percentage of ash & refuse based on dry fuel	%	0.41	0.57	0.53	5.16	0.44	0.35	0.49	0.47	0.68	0.69
(25) Total weight of water fed to boiler	Lb.	151,755	97,960	116,580	127,960	92,435	140,720	132,560	171,855	91,955	127,635
(26) Total water evaporated, corrected for quality of steam (Item 25x Item 18)	"	149,023	96,100	114,248	....	91,233	139,453	131,100	171 855	90,480	125,720
(27) Factor, of evaporation		1.17	1.16	1.18	1.29	1.204	1.2	1.18	1.18	1.19	1.18
(28) Total equivalent evaporation from and at 212 deg. (Item 26 x Item 27)	"	174,356	111,476	134,712	164,068	109,844	167,343	154,700	202,790	107,670	148,350
HOURLY QUANTITIES & RATES											
(29) Dry fuel per hour	"	4,791	2,828	5,175	5,395.8	5,556	5,563	5,048	7,058	3,759	5,129
(30) Dry fuel per sq. ft. of grate surface per hour	"	49.3	23.2	49	48	42.5	42.5	57.9	81.0	37.6	58.8
(31) Water evaporated per hour, corrected for quality of steam	"	14,902	12,022	14,281	21,326.6	15,205	19,919	18,730	22,900	15,080	17,960
(32) Equivalent evaporation per hour from and at 212 deg.	"	17,435	13,934	16,840	27,344.6	18,307	23,906	22,100	27,040	17,945	21,193
(33) Equivalent evaporation per hour from and at 212 deg. per sq. ft. of water heating surface	"	3.96	3.2	3.83	6.16	4.16	3.43	5.02	6.14	4.1	4.82
CAPACITY											
(34) Evaporation per hour from and at 212 deg. (same as Item 21)	"	17,435	13,934	16,840	27,344.6	18,307	23,906	22,100	27,040	17,945	21,193
(a) Boiler horsepower developed (Item (34:—34½)	H. P.	505	404	488	792.7	531	493	640	784	520	614
(35) Rated capacity per hour from and at 212 deg.	Lb.	15,180	15,180	15,180	15,180	15,180	15,180	15,180	15,180	15,180	15,180
(a) Rated boiler horsepower	H. P.	440	440	440	444	440	440	440	440	440	440
(36) Percentage of rated capacity developed	%	114	91.8	110	178	121	158	146	178	118	140
ECONOMY											
(37) Water fed per lb. of fuel as fired (Item 25—: Item 19)	Lbs.	1.58	2.2	1.64	2.56	1.79	2.02	2.0	2.12	2.07	1.9
(38) Water evaporated per lb. of dry fuel (Item 26—: Item 21)0	"	3.1	4.24	2.76	3.92	2.73	3.58	3.71	3.24	3.84	3.5
(39) Equivalent evaporation from and at 212 deg. per lb. of fuel as fired (Item 28—:—Item 19)	"	1.81	2.5	1.9	3.29	2.12	2.40	2.34	2.5	2.43	2.2
(40) Equivalent evaporation from and at 212 deg. per lb. of dry fuel (Item 28—:— Item 21)	"	3.63	4.92	3.23	5.06	3.29	4.30	4.38	3.83	4.57	4 13
(41) Equivalent evaporation from and at 212 deg. per lb. of combustible (Item 28—:—Item 23)	"	3.65	4.95	3.27	5.32	.331	4.31	4.39	3.85	4.60	4.16
EFFICIENCY											
(42) Calorific value of 1 lb. of dry fuel by calorimeter	B. t. u.	9170	8735	8740	8700	8620	8750	9220	8450	9140	8,710
(a) Available calorific value of 1 lb. of fuel as fired (calculated)	"	3920	3734	4561	5178	5069	4315	4315	5076	4231	4,310
(43) Calorific value of 1 lb. of combustible by calorimeter (calculated)	"	9190	8950	8820	8830	8900	8860	9280	8640	9190	8,800
(44) Efficiency of boiler, furnace and grate	%	38.4	54.6	35.8	60.1	37.0	47.7	46.1	44.0	48.5	46.1
(44-a) Efficiency based on fuel as fired	"	44.8	65.0	38.8	49.5	40.5	53.9	52.6	47.8	55.7	49.5
(45) Efficiency based on combustible	"	38.5	53.7	35.9	58.5	36.1	47.2	45.9	43.2	48.6	45.8
FIRING DATA											
(50) Kind of firing		double chute	hand fired	single chute	Riley stoker	single chute	Four Chutes	Two Chutes	Two Chutes	Two Chutes	Two Chutes
(a) Arrangement of furnace		Normal	short grates low bridge	normal	three overfeed chutes	bridge curtain Walls	same as No. 9	short grates same as No. 7	W. C. same as No. 9	Low grates high bridge	grates raised high bridge

to the fuel being so bulky and inconvenient for handling in large quantities, and also because other fuels have been available at prices which make them more attractive. However, recent heavy advances in the cost of coal and oil have driven a few concerns to the use of sawmill refuse. Besides the other large consumers referred to in this article attention is called to the fact that quite a number of small users are now relying upon sawmill refuse which is delivered to them in trucks. Such plants are laundries and the like where the boilers installations are not large. The writer is advised that some ofthese plants are getting their fuel at a very low cost indeed. There is no reason why this class of fuel cannot be used more extensively by such people where reasonable continuous delivery of fuel can be secured.

It is interesting to note that the Portland Railway Light & Power Company has secured very satisfactory results with the use of sawmill refuse fuel on Riley stokers. The fuel fed through the retorts of the stoker is supplemented with additional fuel fed from overhead chutes. Although one can readily understand that the installation of stokers for sawmill refuse fuel would not be warranted, nevertheless, that this class of fuel can be burned on a stoker with satisfactory results makes it possible to shift quickly from coal to mill refuse or back again as the case may require. The Babcock & Wilcox Company, before the war, had prepared an installation of Stirling boilers with Jones stokers for the Washington Pulp & Paper Company, Port Angeles, Washington, which installation was not completed on account of the war.

On account of the recent curtailment in the supplying of oil for fuel purposes it is quite probable that we shall soon see a much more extensive use of sawmill refuse. The writer would be pleased to see stopped the tremendous wasting of materials so satisfactory for fuel purposes, which has continued for so many years.

Pulverized Coal as a Power Plant Fuel

A great deal has been written for and against the use of pulverized coal as a power plant fuel, therefore, a few statements regarding reasons for its utilization as well as citations of some of the installations which are operating successfully will be more convincing as to its merits than a lengthy discussion of its theoretically good qualities.

One of the best reasons for pulverizing coal is that it permits of the utilization of all kinds and sizes of coal with approximately equally good efficiency, whereas, with either hand-fired or stoker-fired boilers the efficiency varies greatly with the quality and size of the coal used. The standard degree of fineness for pulverizing coal for boiler use is 95 per cent through a 100 mesh sieve and 85 per cent through a 200 mesh seive. With this fineness the surface exposed is increased on an average seven or eight hundred times and it is possible to obtain a perfect mixture of these particles with air for combustion.

The northwest territory contains large quantities of low-grade coal and consequently has been and undoubtedly will be a good field for the general use of pulverized coal. The first successful installations in this territory were made by the Pacific Coast Coal Company, of Seattle, Washington. This company now having three pulverized coal plants. One of these, a five ton per hour plant is located at its Black Diamond Mine, Black Diamond, Washington. A subbituminous coal mined at Newcastle, Washington, is shipped to this plant, dried and pulverized and burned under 250 h.p. vertical water tube Wicks' boilers and nine 125 h.p. return tubular boilers. This coal is a very fine buckwheat, all of which passes a 3/16-inch screen and before the advent of pulverized coal was not marketable and had been wasted down a creek and deposited in Lake Washington. During the past winter part of this coal has been reclaimed, some of it being used in this plant and some sold for use in a pulverized coal plant in Seattle.

Another five ton per hour plant is located at Newcastle, Washington, where the coal mined is used under eight 125 h.p. Horizontal Return Tubular Boilers. Both of these plants are so constructed that it requires only one man to operate the machinery. The driers are fired with pulverized coal and all the machinery is driven by one steam engine through belts and line shafting.

The other installation of this company is a nine ton per hour plant built in connection with their Briquet Plant at Renton, Washington, fourteen miles distant from Seattle. This plant is used as a central plant from which delivery is made by railroad cars and auto trucks to small boiler plants in Seattle. The pulverized coal is loaded by a screw conveyer from the mills into a specially designed railroad car and transported into Seattle, where it is stored in an 80-ton bin which is constructed so that the pulverized coal can be fed out by gravity into auto trucks built to haul five tons a load to the various consumers. The coal is unloaded from the trucks by gravity through dust-tight connections into the consumer's bin located in or adjacent to the boiler room.

The following named installations have been made in Seattle:

The Seattle Natitorium	two 100-h.p. horizontal return tubular boilers
The New Richmond Hotel	one 75-h.p. dry back Scotch marine boiler and one 50-h.p. dry back Scotch Marine Boiler.
L. C. Smith Building	one 300- and one 200- h.p. B. & W. water tube boilers
The Broadway High School	three 125-h.p. horizontal return tubular boilers
Independent Laundry	one 85-h.p. horizontal return tubular boilers

Tests of M 22 and S 21 Stirling Boilers burning wet Sawmill Refuse

Boiler Room	MAIN MILL									
Boiler Being Tested	M 22	M 22	M 22	M 22	M 22	S 21	S 21	M 22	M 22	S 21
Date of Test 1914	Dec. 22	Dec. 23	Dec. 24	Dec. 29	Dec. 31	Jan. 2	Jan. 4	Jan. 5	Jan. 6	Jan. 7
Duration of Test	4	4	4	3	4	4	4	4	4	4
Steam Pressure	183.2	180.8	182.2	184.7	184.6	188.0	193.8	184.7	184.7	187.6
Water Temperature	45.8	46	47	47	50	49.0	49.0	50	50	50
Factor of Evaporation	1.2201	1.2198	1.2188	1.2191	1.2159	1.2172	1.2177	1.2159	1.2159	1.2161
Calorimeter Thermometer Reading No. 1	300.6	289.8	298.9	300.7	298.7	311.8	304.6	310.5	300.3	310.8
" " " " 2	374.8	373.4	374.8	376.0	375.5	378.6	380.7	376.4	376.1	377.3
Per cent Moisture in Steam	.56	1.12	.65	.57	.66	0	.46	0	.59	0
Total Actual Water	112533	133357	151631	83292	141774	79305	100682	138008	142328	99353
Total Corrected Water	111903	131863	150645	82817	140838	79305	100219	138008	141488	99353
Total Equivalent Water	136533	160846	183606	100962	171259	96530	122037	167818	172049	120823
Equivalent Water Per Hour	34133	40212	45902	33654	42815	24132	30509	41954	43012	30206
Horse Power Developed	889.3	1165.5	1330.5	975.5	1241.0	699.5	884.3	1216.1	1246.7	875.5
Per Cent of Rating Developed	165.7	195.2	222.9	163.4	207.8	169.2	213.9	203.7	208.7	211.7
Draft in Ash Pit	....	....	....	....	.10	....	....	....	....	....
Draft in Furnace No. 1	.20	.23	.35	.37	.35	.38	.42	.36	.41	.44
" " " " 2	.23	.25	.36	.41	.40	.42	.50	.41	.45	.52
Draft at Top Door 3rd Pass	.56	.69	.85	.88	.90	.80	1.04	.88	.98	.97
" " Boiler Side Damper	....	....	....	....	1.06	1.28	1.26	.94	1.05	1.17
" " Flue " "	....	....	....	1.25	1.20	....	....	....	....	....
" " Base of Stack	....	....	....	....	1.30	....	....	....	....	....
Furnace Temperature	....	1950	2019	....	1920	....	....	....	....	....
Flue "	514	574	582	527	590	585	681	572	564	674
Air "	50	55.7	53.1	36.5	53.2	48.7	45	49	53	55.2
Flue Gas Analysis CO_2	16.90	17.28	17.86	12.91	16.5	11.8	11.45	17.3	16.9	11.7
Flue Gas Analysis O_2	2.03	2.35	1.68	7.39	3.2	8.7	8.92	2.0	2.1	8.8
Flue Gas Analysis CO	1.56	1.11	.95	.26	.8	.1	.10	1.1	1.4	.0
H. P. Per Sq. Ft. Grate Surface	7.38	8.66	10.00	7.33	9.33	7.48	9.46	9.14	9.37	9.36
Per Cent Moisture in Fuel	40.44	42.83	42.71	46.49	40.06	40.48	40.40	44.20	45.48	44.41
Conditions	Regular Plant Conditions	Damper set to give 7 in. draft at top 3rd Pass	Damper wide open Careful Firing Baffel at top 3rd pass opened up	Damper wide open Heavier Fuel Piles. Poor Firing	Same condition as Dec. 24th	Regular Plant condition Standard Baffling	Damper Wide Open Baffle at top 3rd pass opened up.	Holes in ash pit walls Damper wide open	Same as Jan. 5th	Same as Jan. 4th

Boiler Room	EASTSIDE MILL							
Boiler Being Tested	M 22	M 22	M 22	M 22	M 22	M 22	M 22	M 22
Date of Test 1914	Jan. 15	Jan. 16	Jan. 18	Jan. 25	Jan. 26	Jan. 28	Jan. 29	Feb. 3
Duration of Test	4	4	4	4	4	4	4.33	4
Steam Pressure	136.7	139.5	143.0	140.4	142.0	143.2	142	142.3
Water Temperature	47	47	46	44	44	47	48	50
Factor of Evaporation	1.2144	1.2147	1.2162	1.2180	1.2182	1.2152	1.2140	1.2120
Calorimeter Thermometer Reading No. 1	303.5	302.2	298.2	302.9	....	301.5	301.3	....
" " " " 2	....	....	....	....	....	....	....	....
Per cent Moisture in Steam	0	0	.33	0	0	0	0	0
Total Actual Water	89606	89163	123830	125040	114305	119843	125603	128375
Total Corrected Water	89606	89163	123421	125040	114305	119843	125603	128375
Total Equivalent Water	108817	108306	150105	152299	139246	145623	152482	155590
Equivalent Water Per Hour	27204	27076	37526	38075	34812	36406	35188	38898
Horse Power Developed	788.5	784.8	1087.7	1103.6	1009.0	1065.2	1019.9	1127.4
Per Cent of Rating Developed	130.8	130.1	180.4	183.0	167.3	175.0	169.1	187.0
Draft in Ash Pit	....	....	....	....	....	....	....	....
Draft in Furnace No. 1	.18	.13	.22	.27	.27	.30	.27	.27
" " " " 2	.20	.15	.26	.31	.29	.33	.29	.31
Draft at Top Door 3rd Pass	.43	.29	.74	.78	.82	.74	.75	.77
" " Boiler Side Damper	....	.56	.85	.88	.94	.84	.86	.88
" " Flue " "	....	....	....	....	....	....	....	....
" " Base of Stack								
Furnace Temperature	....	....	2000	1755	1702	1802	1808	
Flue "	530	499	603	597	615	555	588	585
Air "	50	48	51	....	....	....	....	....
Flue Gas Analysis W CO_2	14.4	14.0	14.5	15.3	13.4	16.4	14.5	15.7
Flue Gas Analysis W O_2	5.6	5.9	5.6	4.8	6.8	3.2	5.8	4.5
Flue Gas Analysis W CO	.5	.6	.3	.3	.2	.9	.2	.2
H. P. Per Sq. Ft. Grate Surface	5.93	5.90	8.17	8.30	7.59	7.93	7.67	8.47
Per Cent Moisture in Fuel	52.72	40.18	40.35	44.96	53.21	47.27	44.60	43.51
Conditions	Plant conditions White Cedar White Fir	Plant conditions fuel principally Yellow Fir	Damper wide open all Yellow Fir Fuel Baffle opened	Damper wide open Bridge Wall Grate W. Cedar W. fir	Same as Jan. 25th More W. fir in fuel	Secondary air cut-off otherwise same con. as Jan. 25.	Secondary air open Heavier Fuel Piles.	Damper Wide open 2nd air open. Fuel nearly all W. Cedar

The installation in the L. C. Smith Building has brought forth considerable favorable comment, due to its simplicity and neatness, as well as the central location of the building and its fame as a 42-story building.

The above mentioned commercial installations are unique in that the powdered-coal storage bins are located some distance from the boilers and not in the same rooms. This was done to conserve valuable space in the boiler rooms and in some instances to facilitate delivery from tank trucks. The pulverized-coal feeders are located beneath these bins and are driven either by friction or variable speed motors and in either case the controls are located in the boiler rooms. Primary air pressures, varying from one and a half to three pounds, are used for mixing and conveying the coal to the boiler furnaces, this pressure depending upon the distance and number of bends in pipe lines. This air is admitted at the feeders, induces with it additional air for combustion and transports the pulverized coal through pipes laid beneath the floor to the boiler furnaces. These pipe lines are so equipped with gates and valves that any or all of the boilers may be fed from any part of the storage bins. These storage bins vary in capacity from six to twenty-five tons, the larger ones being built of concrete and the smaller ones of steel. The boilers of all of these installations were formerly fired with oil and due to low boiler settings it was practically impossible to enlarge furnaces, and outside of removing the grates no changes were made in them. Nevertheless the operation of these boilers has been quite satisfactory, undoubtedly due to the fact that in all but one of the installations boilers are operated at not more than their rated capacity though in this one case, boilers have been operated at from 150 to 200 per cent rating, but not for more than a six-hour period.

The Puget Sound Power & Light Company formerly used fuel oil in their Western Ave. Steam Heat plant, but during the first part of 1917 at the time the price of oil was advancing and oil companies were refusing to contract for future deliveries on account of war conditions, they decided to run some tests on pulverized coal because they desired to determine what fuel could be best used to displace the oil. Coal for these tests was dried and pulverized at the Briquet Plant of the Pacific Coal Company, at Renton, Washington, and transported to their plant in a specially constructed railroad car. All the various kinds of coals, including lignites, sub-bituminous and bituminous mined in the vicinity of Seattle were tried out and it was demonstrated that approximately equally good efficiencies were obtained with all these coals.

As a result of these tests this company started the erection of a pulverized coal plant and the equipping of 4100 h.p. of Babcock & Wilcox water tube boilers with pulverized-coal burning equipment. This plant was completed in 1918 and has been operating since that time. The greater amount of coal used in this plant is a washery sludge coal from this company's mine at Renton, Washington. This sludge coal is of a very fine size, about 50 per cent will pass a ten-mesh seive. This size renders it totally unfit for use in any existing form of mechanical stoker. About 200,000 tons of this coal have accumulated during the past fifteen years. By analysis it runs 20 per cent moisture, 25 per cent ash, and about 7500 B. t. u. per pound. This coal is very difficult to handle to conveyers and driers, but nevertheless it has proved, when pulverized, to be an efficient fuel, so that this plant has provided a way of utilizing the coal that heretofore has been worthless and even an expense, as it was necessary to provide a place for its storage. It is interesting to note that the average evaporation at this plant is about five pounds water from and at 212 degrees Fahrenheit per pound coal as received. Test results indicate an evaporation even better than nine pounds per pound dry coal Issaquah screenings containing 11,400 B. t. u. per pound.

The other large boiler installation in the Northwest using pulverized coal is the one located at Vancouver, British Columbia and owned by the British Columbia Sugar Refining Co. This plant is using a coal from Vancouver Island, which runs between 25 and 30 per cent ash but has given very good boiler efficiencies during the fourteen months of the plant's operation. With Nanaimo bituminous slack this plant on test has had about eight pounds evaporation per pound dry coal containing 9364 B. t. u. per pound. Complete reports of these tests have previously been published and need not be repeated here.

Other concerns using pulverized coal in this section are three cement companies, which are using a sub-bituminous coal of quite high moisture and ash content and also the Tacoma Smelter, where the pulverized coal is fired in a reverberatory furnace used for smelting copper ore. This furnace is provided with two 500-h.p. Stirling waste heat boilers, which develop about 1000 h.p. with an evaporation of five pounds of water per pound of coal fired to the furnace. This is being accomplished with a coal of 11,000-B. t. u. value.

In this Northwest territory there are large deposits of low-grade lignite and sub-bituminous coal yet to be developed, whereas, practically all of the fields of better grades of coal have been developed and operated for a considerable time and the estimated life of these properties is fairly short. So it is reasonable to suppose that the source of fuel supply for this territory will in the future have to be from the poorer grades of coal, and as the attempts to burn these coals with mechanical stokers and by means of gas producers has been unsatisfactory, pulverized coal will undoubtedly become more generally used.

The utilization of the poor grades of coal by pulverizing is not confined entirely to the Northwest territory. In the anthracite fields of Pennsylvania the old culm piles are being used in this way. The N. A.

Hanna Company, at Lytle, and the Susquehanna Collieries at Lykens have made installations at their boiler plants and have been obtaining very high efficiencies and general good results.

The writer understands that order has recently been placed by the Milwaukee Electric Railway & Light Company, Milwaukee, Wisconsin, for powdered coal burning equipment for a new 40,000-kw. station to contain eight 1308-h. p. boilers to be operated at 250 per cent of their rated capacity continuously. This same company has at present in operation five 468-h. p. boilers which installation was operated so successfully that the new plant will be equipped with similar coal-burning machinery.

The Bethlehem Steel Company has just recently put into operation a plant containing four 500-h. p. boilers with furnaces designed for powdered coal to operate continuously at 150 per cent of rated capacity of the boilers. The coal at present being burned is pumped from the Susquehanna River; it is an anthracite coal and a notable feature of the installation is the type of burner which throws a fan-shaped flame vertically downward. This arrangement seems to permit the heat to penetrate the flame very rapidly and very quick ignition of the fuel is secured. The boilers are operated with induced draft fans and back of each boiler is a Green economizer, and the installation has proved so satisfactory that this same company is contemplating the installation of pulverized coal for all of its boilers in this power house at Lebanon as soon as it is able to secure the pulverizing equipment. This same company has been using pulverized coal for certain parts of its work for approximately fifteen years and is therefore very familiar with its general operation.

The writer also understands that Mr. W. B. Uihlein of Milwaukee, Wisconsin, is installing a plant in connection with a food produce manufacturing establishment to contain four 500-h. p. boilers designed to operate at 200 per cent rating.

It is of course not necessary that a poor grade of coal be used in a pulverized coal installation; the better coals will evaporate more water per pound or per ton and are therefore more desirable.

A great deal has been said about the difficulty with ash and fine dust coming from the stack of a powdered coal installation. The amount of this ash seems to depend in considerable measure upon the kind of coal being burned, and the quality of the ash. If the ash is very fine and light it is easily carried out of the boiler setting with the force of the draft, in other cases the ash may be heavy enough to deposit in the boiler setting or in settling chambers provided for that purpose. It seems that it is very desirable where a plant is installed in a thickly settled district to provide some means of taking care of this ash. A very tall chimney will of course distribute ash in smaller quantities over a wider distributed area and this may suffice in the majority of installations, however, there is a certain amount of ash which comes out of any stack burning powdered coal and the time may come when it will be necessary to take care of this.

In the city of Seattle where powdered coal plants are in operation in the heart of the city, we believe that there has been no recent complaint on account of the ash, however, it is quite evident that some ash is being scattered around and the greater use of powdered coal might cause this to become such a nuisance as to call for legislation.

On account of the ability to light powdered coal quickly, to put it out quickly, and to carry heavy overloads quickly where necessary, it seems probable that this fuel will find a field of usefulness not only in order to take care of poorer grades of coal but also in stand-by plants where the above features are of very considerable importance.

It is interesting to note that the Pacific Coast Coal Company recently fired some powdered coal which had been in storage for almost a year and found that it worked very satisfactorily. They had no difficulty in keeping the coal in storage for this length of time, as being perfectly dry there was no evidence of overheating.

Since practically all tests of powdered coal installations have been published and as there are no recent tests in the Northwest territory which have not been published, the writer is not endeavoring to restate these here.

Fuel Oil

There has recently been a great deal in the papers and a considerable discussion about the probable shortage of fuel oil in the near future, and it is certainly a fact that a number of users have been notified that they will have to rely upon some fuel other than oil to carry their load. The writer believes that none of the oil companies are writing any new contracts at the present time. However, it is very probable that oil fuel will be used for many years to come, and although a great deal has already been written about oil, nevertheless, some features of its use which are being developed from time to time will be interesting to those who are fortunate enough to have this fuel available for their use.

It is the understanding that the production of oil last year was the largest in the history of the production of crude oil in the United States, and totaled over a million barrels of oil per day. The present apparent effort on the part of the oil companies to curtail the use of this fuel is evidently on account of the depletion of their reserves. At the beginning of 1918, there were approximately one hundred and forty million barrels of oil in storage; at the end of 1918 in the United States there were probably not more than about one hundred and twenty million barrels, and at the end of 1919 there were about one hundred and twenty five million barrels in storage in the United States. Although there has been a slight gain in the amount of oil in storage during

the last year this is still not back to the normal pre-war amount. The writer understands further that the storage accumulated during the winter is depleted during the summer months, and there is threatened to be a really severe shortage this present summer.

There has been published some information in periodicals to indicate that at the present rate of consumption the available fuel oil in the United States will be used up in about twenty years. The writer questions this very much and of course the present rate of production will probably not be kept up. It also seems probable that other sources of supply of oil will be discovered to increase the present known oil-producing districts. However, it does seem probable that there is going to be an increase in the cost of fuel oil, which may be so marked as to make it necessary for us to confine the use of this fuel to certain installations where it is particularly advantageous or in standby plants where it is an ideal fuel.

The writer wishes at this time to call particular attention to the use of fuel oil in standby plants. There has been so much information published in connection with the general use of fuel oil that reports of tests of the ordinary kind at this time would add little to the information which we all have. Ability to get up steam in a cold boiler in 30 minutes and to be operating the boiler at 200 per cent of rating or more in a very few minutes thereafter makes this fuel ideal for emergencies in standby plants.

In considering the use of oil fuel in standby stations, where it is frequently necessary to carry heavy overloads, it is desirable to secure as high evaporative efficiencies as is possible at these heavy overloads. Records of tests with oil fuel have in general indicated a considerable falling off in efficiency as soon as the boiler was operating at a little above its rated capacity. This is a condition which is to be expected and applies to any fuel, but experiments have been made with apparent success to indicate that we can secure better efficiency at overloads than we have been accustomed to getting in the past.

Through the courtesy of the Babcock & Wilcox Company the writer is permitted to publish some tests made at the Bayonne Works of the Babcock & Wilcox Company on a Babcock and Wilcox boiler, with a mechanically atomizing oil burner of the Lodi type, which is the latest development in oil burners by that company.

The results of the tests of the mechanical oil burners are shown in the table which is so marked. The average results are indicated by a curve shown in Fig. 1 which, also shows a curve for the net efficiencies obtainable with steam atomizing burners. By net efficiency is meant the efficiency based on the total steam evaporated less the steam blown to waste in atomizing the oil.

Fig. 2 shows a Lodi burner, the parts being numbered and the functions of the parts being indicated thereon.

There are a few features of particular importance brought out by these tests. It will be noted that the efficiencies are well maintained even at very heavy overloads. The other remarkable feature is that in a very restricted furnace volume enormous quantities of oil were burned and even at the high percentages of rating the combustion, as indicated by the flue gases analysis, was maintained very uniform.

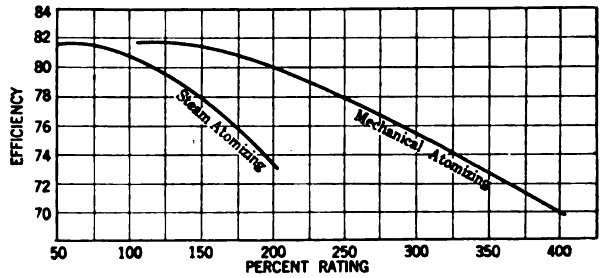


Fig. 1

The use of mechanically atomizing oil burners has been very extensive in marine practise for a number of years but in stationary work experiments heretofore have failed to indicate that there was a marked advantage in their use. It seems to be true that efficiencies with steam atomizing oil burners can be secured as high as or probably higher than with the mechanically atomizing burner, but the writer believes that there have been no tests with steam atomizing burners at ratings equivalent to those reported in the tests herein where efficiencies were secured as high as are shown by those tests.

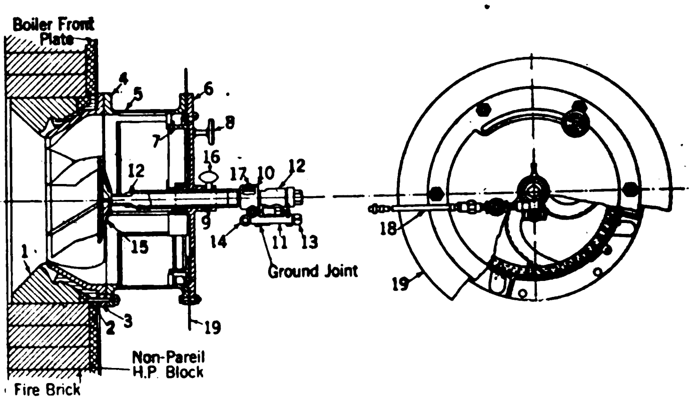


Fig. 2—Lodi Oil Burners

1. Fire Brick Moulded Tile
2. Grid for Holding Tile
3. Bladed Cone
4. Main Register Casting
5. Automatic Air Doors
6. Cover Plate
7. Spider with Cams
8. Handle for Locking Spider
9. Distance Piece
10. Quick Detachable Coupling
11. Quick Detachable Yoke
12. Mechanical Atomizer
13. Bolt for Setting Up Ground Joint
14. Hinge
15. Center Impeller
16. Wing Set Screw
17. Headless Set Screw
18. Flexible Oil Connection
19. Radiation Guard

The Babcock & Wilcox Company is still experimenting with mechanical atomizing oil burners for stationary boiler plants and it is to be understood that later developments may make it possible to secure results even better than those reported herein. However, these results are so satisfactory that it seems

probable that there is a big field for the use of this type oil burner. The Portland Railway Light & Power Company is now installing a Stirling boiler to be equipped with Lodi oil burners.

OIL BURNER TEST—BABCOCK & WILCOX BOILER
BAYONNE, NEW JERSEY
450 Horsepower—15.45 per cent Superheating Surface
445 Cu. Ft. Furnace Volume.

Number of Test	41	42	43	44	45
Date of Test 1919	Aug. 14	Aug. 15	Aug. 15	Aug. 21	Aug. 21
Type of Burner			Lodi		
No. and size of Sprayer Plate	3–47–2	3–40–2	3–40–2	3–104	3–25–1.1
Duration of Test—Hours	6	4	4	2.5	3.58
Steam Pressure—lb. per sq. inch	178.2	178.4	177.9	186.2	192.1
Steam Temperature—Deg. Fahrenheit	453.6	466.9	482.3	504.9	530.4
Superheat—Deg. Fahrenheit	74.7	88.0	103.6	122.6	146.1
Feed Temperature—Deg. Fahrenheit	71.9	70.35	72.3	70.8	71.6
Factor	1.2394	1.2484	1.2549	1.2675	1.2798
Oil Pressure at Burners—lb. per sq. inch	169.7	120.3	194.7	193.2	188.7
Oil Temperature at Burners—Deg. Fahr.	250.7	252.6	248.2	258.6	232.7
Total Oil Burned—lb.	7016	6245	8171	6558	12663
Oil burned per hour—lb.	1169.8	1561	2042.8	2623.2	3537.1
Oil Burned per hour per burner—lb.	389.8	520.4	680.9	874.4	1179.0
Temperature of Flue Gases—Deg. F	413	443	485	523	6.16
Temperature of Room—Deg. F	81	86	89	93	97
Draft Inside Damper—Inches of Water	.24	.40	.71	.77	.72
Draft in Furnace—Inches of Water	.14	.18	.24	.21	.17
Air Pressure in Duct—Inches of Water	.22	.44	.75	1.82	3.64
CO_2 } 3rd Pass	13.77	13.71	13.53	13.41	13.70
O } 3rd Pass	2.26	2.30	2.61	2.94	2.65
CO } 3rd Pass	.05	.06	.04	0	.05
Total Water Fed Boiler—lb.	87515	77733	98928	77098	139722
Total Water From and at 212 deg.—lb.	108466	97041	124145	97722	178816
Water Per Hour From and at 212—lb.	18078	24260	31036	39089	49947
Actual Evaporation per lb. of oil—lb.	12.47	12.45	12.11	11.76	11.03
Equiv. Evaporation fr. and at per lb. of oil—lb.	15.46	15.54	15.19	14.60	14.12
Water fr. and at per sq. ft. of H. S.	4.02	5.39	6.89	8.69	11.10
Horse Power Developed	524.0	703.2	899.6	1133.0	1447.7
Per cent Rating	116.4	156.3	199.9	251.8	321.7
Efficiency—Per cent	81.80	81.41	79.05	77.91	75.29
Gravity of Oil-Baume	15.3	15.3	19.5	15.3	17.0
Per cent Moisture in Oil					
B. t. u. per lb. of Oil.	18340	18530	18650	18560	18200

In boiler plants, using oil fuel, where overloads are frequently carried, there has always been a great deal of trouble with refractories. This is particularly the case on the Pacific Coast where the fire brick are not of the very first quality and where the extensive use of oil fuels has forceably brought to our attention the fact that one always has to allow for certain shut-downs for repairs to the furnace brick work.

To help overcome the difficulties with the brick work it has been customary for us to figure on increasing our furnace volumes, particularly where it is necessary to carry overloads. Certainly these increased furnace volumes have helped but have not entirely overcome the difficulty, and the cost of such large furnaces both on account of brick work and the space occupied may be very considerable. With the mechanical oil burner of the type used on the tests above it is evident that since such satisfactory combustion can be secured in a rather limited furnace volume it is reasonable to suppose that we can get along with this type burner in very much smaller furnaces than is possible with steam atomizing burners and still not increase the difficulties with brick work that have been heretofore experienced. The mechanical burner makes efficient use of a much larger percentage of the furnace volume than does the other type, on account of the shape of the flame. The burner makes a much shorter flame than the steam burner because of the finer atomization of the oil and should not require any extra protecting wall in the furnace, such as is frequently used with steam burners.

With mechanical burners it is necessary to have a greater furnace draft than where steam is used, as the air must be delivered at high velocities in order to secure an intimate mixture with the oil. This draft pressure can be either induced or forced as may be necessary. By referring to the tests one will note that it is not necessary, even at heavy overloads, to carry excessive oil pressures, these being well below average steam pressures in modern plants. Temperatures and pressures unquestionably will vary with the quality of the oil but it is probable that even with the heavier oils now being sold no difficulty will be experienced along these lines.

The writer does not wish to recommend unreservedly operating boilers at as heavy overloads as can be secured with this type mechanical burner, because such operation requires the most careful attention; boilers must be clean; and the feed water of the best quality. We usually find very excellent water in the Northwest territory, but in certain plants it may be necessary to purify or distill the make-up and in such instances the mechanical burner eliminates the loss with the steam atomizer.

With the ordinary steam atomizing burner it is frequently necessary to take the burner out and clean it. This seems to be particularly true of the more efficient types of burners using small amounts of steam for atomizing, whereas, with the mechanical oil burner of the type used in the above tests very little difficulty is experienced with burners clogging, although, of course, this trouble cannot be eliminated if the oil is not properly strained, but there is not the probability of carbon

depositing on the burner tip as is frequently the case with the steam atomizers.

The mechanically atomizing burner operates very quietly and on that account in certain installations it would be preferred. Fires are easily lit and put out and burners can be quickly and easily removed. On account of the size and shape of the flame it is also most readily adaptable to installation in existing coal furnaces where oil might be used as an emergency fuel.

In comparing net efficiencies of mechanically atomizing burner installations with the steam atomizing burner one cannot assume that the steam used with the steam atomizing burner is entirely eliminated in case of the mechanically operated burner, for it is necessary to use more steam to raise the oil to a higher temperature and to deliver it at higher pressure in the case of the mechanically atomizing burner. However, the amount of steam used to heat the oil and to deliver it at the pressure required in the one case is probably not as much as the steam used to heat, pump and atomize the oil in the other case, and this is particularly true in the average plant where the greatest care is not exercised in controlling the steam to the burner resulting in a considerable waste at this point.

Summary

Summing up the information contained in this article it seems probable that it will be necessary to curtail somewhat further developments in the use of oil fuel. This leads to the greater consideration of coal which will unquestionably be more extensively used in the future, both in stokers and in powdered form. There is a limited field for the use of sawmill refuse, but where it is possible to secure this fuel at approximately present prices it can unquestionably be used to greater advantage, and a more extensive use of it may develop a better and more efficient means of handling and burning it than we have at present.

A PARABLE ABOUT THE MEAN RADIUS OF THE ELLIPSE

At the recent annual convention of the American Institute of Electrical Engineers a rather heated discussion took place regarding the definition of the power factor of an unbalanced polyphase system. A Joint Committee's report was presented in which N. E. L. A. members participated, and two conflicting definitions were presented. Among those who took part in the discussion was Professor Vladimir Karapetoff, Cornell University, who was opposed to the very concept of power factor in application to an unbalanced polyphase system, and called the procedure "pouring new wine into old bottles." To illustrate his point he told the following parable which created considerable amusement among those present, and helped to swing the consensus of opinion to the rational view advocated. "In a certain country, at a certain stage of its development, the circle used to be the only curve known, and any objects that could not be made square or rectangular were made of circular cross-section. It came to pass, however, that in the course of industrial development the advantages of a flattened circle or ellipse were gradually realized. At first the forms of the ellipse used departed but slightly from the circle, and everyone was speaking about 'the mean radius of the ellipse' without thinking of any exact definition of the term. By and by more oblong forms of the ellipse began to be used, and with them came ambiguities, controversies and even law suits, until it became necessary to appoint a joint committee for the definition of the mean radius of the ellipse.

"The committee began its activities by holding a public hearing to consider the interests of those concerned. First came the representatives of makers of canned meats who stated that the public preferred elliptical boxes of the same height and contents as the former round boxes. So these representatives wanted the mean radius of the ellipse defined as that of a circle of the same area. Next came the makers of labels to go around the sides of the same boxes. They complained that they could not figure out correctly the length of the paper strip for the new elliptical boxes and they wanted the mean radius of the ellipse defined as that of a circle of the same circumference and not of the same area. Finally came the representatives of elliptical pie makers, who wanted two separate definitions for the mean radius of the ellipse. According to them, for selling purposes, the largest radius of an elliptical pie should be defined as its 'equivalent mean arithmetical radius', irrespective of the other dimension. For purposes of taxation the shortest radius should be used and defined as the 'equitable mean geometric radius'.

"The committee was in great difficulty to decide among these proposals, when a shabby looking underpaid college professor appeared and bashfully ventured the opinion that the thing really needed was not a fictitious definition of a mean radius of the ellipse, but a careful study of the actual properties of the ellipse. Then, he continued, the area as well as the circumference of the ellipse could be expressed in terms of its dimensions, and each industry could be provided with the needed data. Besides, such an investigation would open the way to further progress in the arts.

"The rest of the committee and the audience did not like this speech; they rent their garments in wrath, and they took the blasphemous man out of their city to be stoned. Then they delivered him to the judge and the judge delivered him to the attorney general, to be deported with other radicals and criminals who preached violence".

Gaseous Conduction Light From Low-Voltage Circuits

BY D. McFARLAN MOORE

Moore Light Dept., General Electric Co.

THE production of artificial light is one of the most important activities concerning the welfare of humanity. It is a very large subject, since both its practical and theoretical aspects cover vast fields. Yet, there are less than a dozen distinct methods of making light artificially, and some of them are not developed commercially, although theoretically, they possess great possibilities.

This paper is written to consider some of these methods of producing artificial light that have to do with electricity and that come under item 5 of the following list:

1. Torch (and candle)
2. Oil,
3. Gas,
4. Solid Electric Conductors,
5. Gaseous Electric Conductors.

Electricity can be used to agitate into light either solids or liquids or gases. The light of the incandescent lamp is due to electrically-heated solids, and when electricity is conducted by a gas under suitable conditions, light also results. Many varieties of lamps of this nature both in design and construction are indicated in Fig. 1, the scope of which can be enlarged almost indefinitely; for example, by the use of many other gases and vapors.

High-tension lamps require the special auxiliary transforming apparatus to generate the high potential.

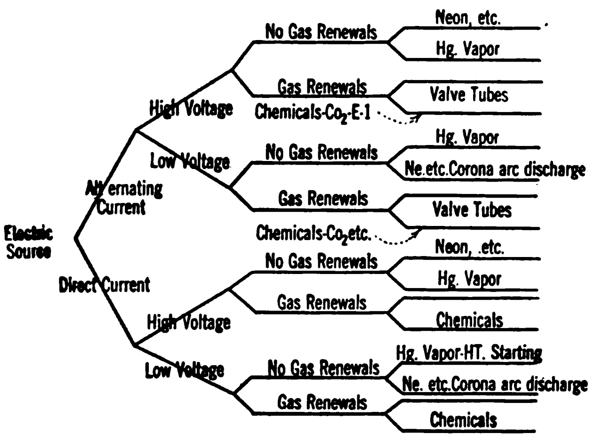


FIG. 1

The two major factors of all of these types are (1) the electrodes, (2) the gaseous conductor.

Both electrodes of alternating-current lamps can be similar, but in direct-current lamps the cathode differs from the anode. Electrode materials differ with the gas used. It is therefore seen that the construction and design of each one of the scores of lamps indicated, is a distinct, and difficult problem, the solution of many of which, has hardly been seriously attempted.

As might be surmised the specific type of lamp I wish to emphasize, is the one that I have been most interested in recently, but in order to give it its proper setting, it is necessary to hastily review the past. The first natural electric light was lightning, or the aurora. It was due to gaseous conduction and so also

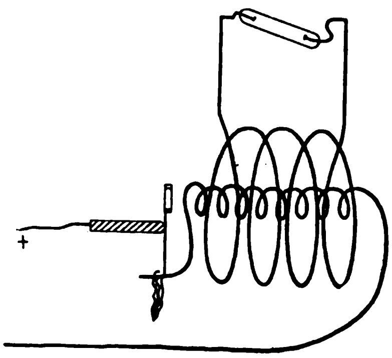


FIG. 2

was the first artificial electric light, which was produced with the revolving glass sphere of Hawksbee in 1750.

A hundred years later, Geissler first operated his small tubes from an induction coil. See Fig. 2. In 1879 Crookes modified them in many ways including obtaining high vacua. About 1891 Nickola Tesla delivered his famous lectures on "High Voltage and High Frequency."

Due to the rapid and very objectionable blackening that was deposited over the inside of incandescent lamp bulbs in 1893, I first began talking and thinking about the possibility of constructing a lamp without a heated filament—a filamentless lamp. In connection with the American Institute of Electrical Engineers, I explained that I meant a bulb form of lamp, the light source of which was to be, not an incandescent solid conductor but to emanate instead, solely from the enclosed gas or vapor electrically agitated by the low-tension circuits in common use.

During the twenty-six years that have intervened, this simple thought has never left me, though the tortuous road has been very dark at times, but it is now brighter than it has been before.

In order that I may not be misunderstood, I must hasten to say, perhaps sorrowfully, that it is still far too dim to even think of its competing in brilliancy with that splendid array of present day commercial illuminants—led by the incomparable tungsten lamp. Dreaming about the "Light of the Future" resulted in the effect shown in Fig. 3.

My first attempts in 1893 to obtain any light from

Presented at a meeting of the New York Section, A. I. E. E., March 26, 1920.

a lamp without a heated filament on 220 volts, resulted in no light whatever. All known gases were unsuccessfully tried. Light from many of the common gases proved very interesting; for example, the bluish white light from CO_2, or the pinkish, hot and almost non-luminous light of hydrogen or the efficient orange yellow light of nitrogen, or the dull whitish light of oxygen; also many mixtures were tried together with chlorine, bromine, etc., and various vapors like those of sulphur or mercury. The prediction was made that progress would only result after the discovery of some of the gases indicated by the table of the periodic law of the elements. It was necessary therefore, in 1894, to resort to the high voltage of an induction coil,

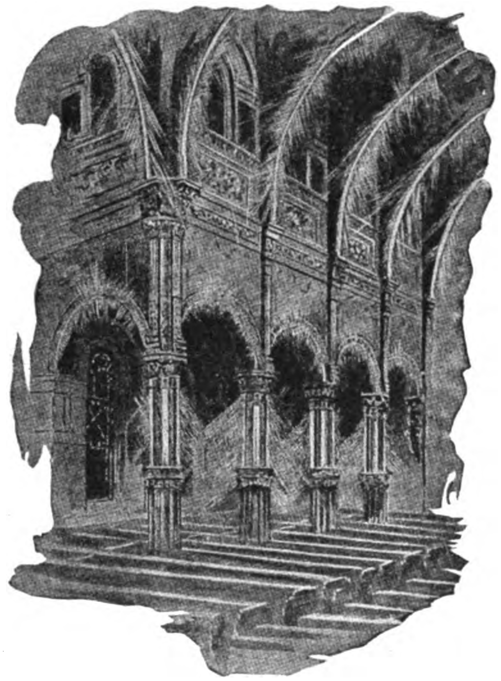


FIG. 3

in order to obtain some light from the first gaseous conductor bulb lamp. In 1895, the vacuum vibrator displaced the induction coil and on direct-current circuits, the bulb lamps were filled with negative glow light. See Fig. 4 which shows vibrator and connections and Figs. 5 and 6 showing negative glow lamps and Fig. 7 depicting the use of negative glow for advertising purposes and means for increasing its intensity. Detailed information of the nature will be found in some of my previous papers.[1]

After neon was discovered as hoped for, and I made nineteen years later, the first low-voltage gaseous conductor lamp, there was a certain satisfaction in proving that my original conception of utilizing the feeble light of the almost despised negative glow was correct. In 1896, seven foot vacuum tubes with external electrodes displaced the bulb lamp. See Fig. 8 for circuits. Fig. 9 shows the meeting hall of the A. I. E. E. thus lighted.

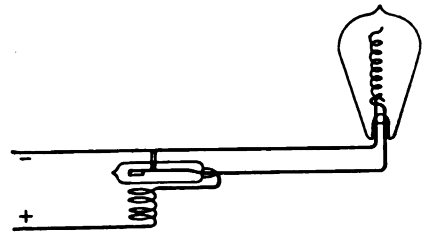


FIG. 4

The vacuum rotator succeeded the vibrator in 1897 and 98. Fig. 10 shows the Rotator Cabinet and Fig. 11 the interior of the historical "Moore Chapel." The first 220-volt direct-current tubes, started with a higher potential, from both vibrator and rotators were made and used. See Fig. 12 for the 5-in. tube which was used in taking the first instantaneous

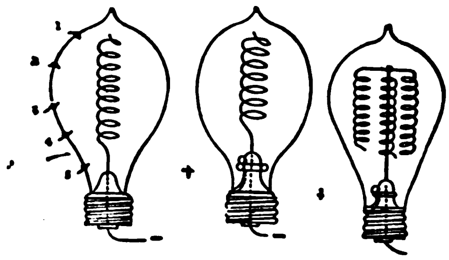


FIG. 5

electric portrait, Chauncy M. Depew being the subject.

The anticipated discovery of neon was announced in 1898, but even samples of it were impossible to obtain in America. Sir Wm. Ramsey, Lord Raleigh, Travers, and their brilliant contemporaries announced in rapid succession the five new monatomic elements, argon, helium, neon, xenon, and krypton, all of which

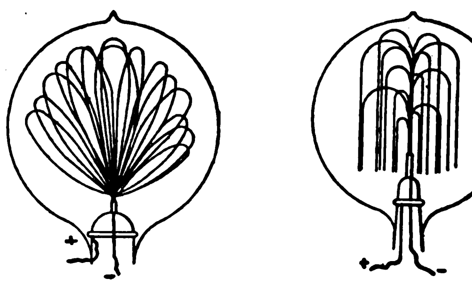


FIG. 6

will probably ultimately take important places in the world of commerce and some of which have already done so.

Vacuum-breaks were displaced in 1899, for a combination of resonance coils and a low-frequency generator, and later high-frequency generators. As shown in Fig. 13 the laboratory was thus lighted.

A New method for the Control of Electric Energy, TRANS. A. I. E. E Sept. 20, 1893.

Recent developments in Vacuum Tube Lighting, TRANS. A. I. E. E. April 22, 1898.

Light from Gaseous Conductors within Glass Tubes, Moore Light, TRANS. A. I. E. E. April 26, 1907.

In 1902, the "long tubes" (about 100 feet) appeared and they were improved in 1903 with internal electrodes. The beauty of the first long tube (Fig. 14)

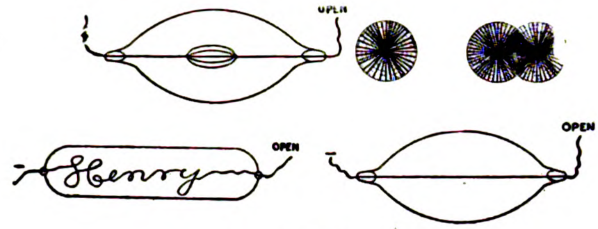


FIG. 7

was admired by thousands. The first rotary high vacuum oil pump was developed for the exhaustion of "long tubes" built in situ. Also a 24-in. CO_2 tube

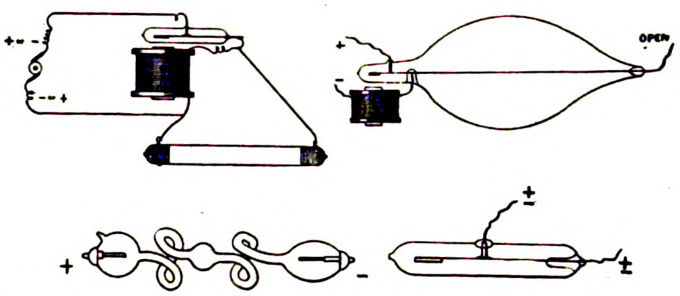


FIG. 8

lamp provided with a carbon filament cathode was started with higher potential on 220-volt direct current and the resultant light was highly efficient.

Other though similar tubes and lamps, had metallic cathodes buried in lime, etc., and it was noted that

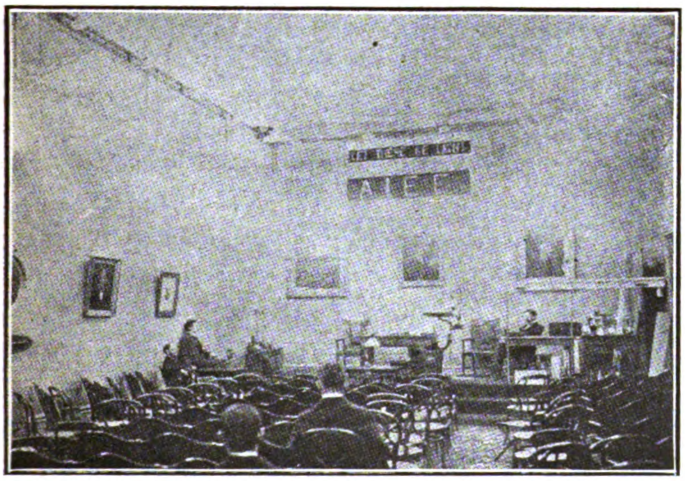


FIG. 9

when operated on alternating current, rectification took place. The combination of chronium and boron nitride with neon and also with some of the gas-feeding methods looks promising. These interesting types of lamps are shown in Fig. 15.

It was a great advance in 1904, and 1905, to discontinue the use of a special generator with each "long tube" installation and obtain brilliant illumination from the distributed street circuits, by the use of nitrogen gas. See Fig. 16. Special electrodes were

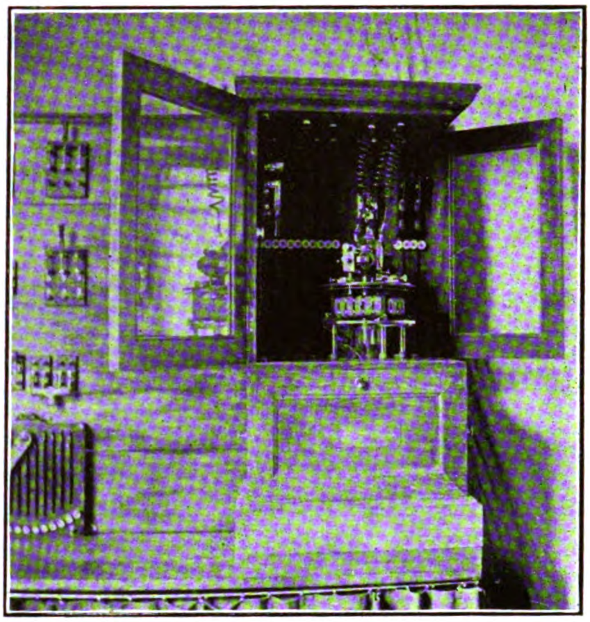


FIG. 10

also constructed with auxiliary circuits, similar to those later used in rectifiers, pliatrons, and X-ray tubes.

The life of these long tubes was extended to 10,000

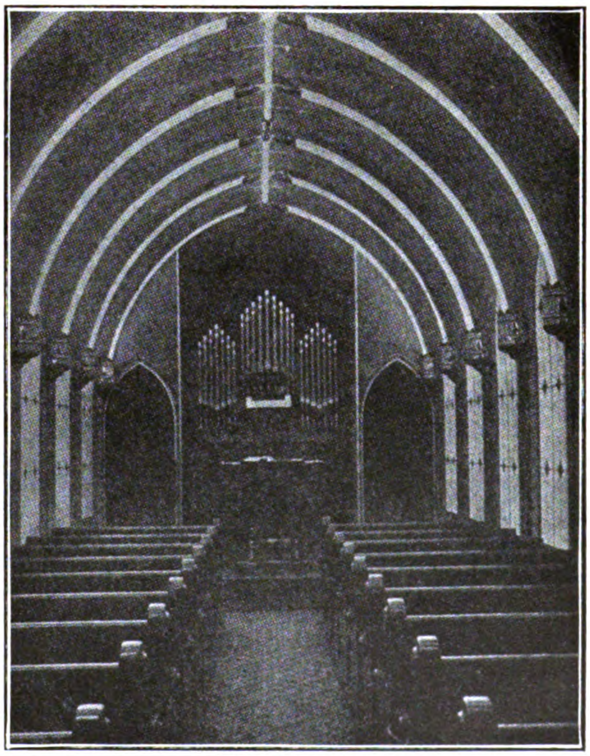


FIG. 11

hours, 1906—1909, by the invention of the electromagnetic feed valve, and over four miles of light-giving tubing was commercially installed. The lobby

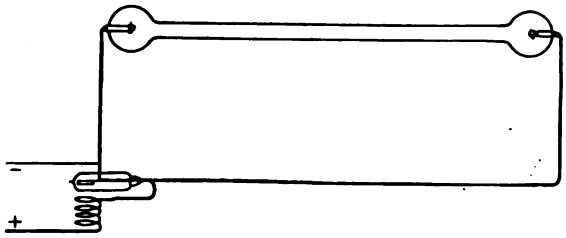


FIG. 12

of Madison Square Garden is shown in Fig. 17. Fig. 18, shows the details of the magnetic feed valve and Fig.

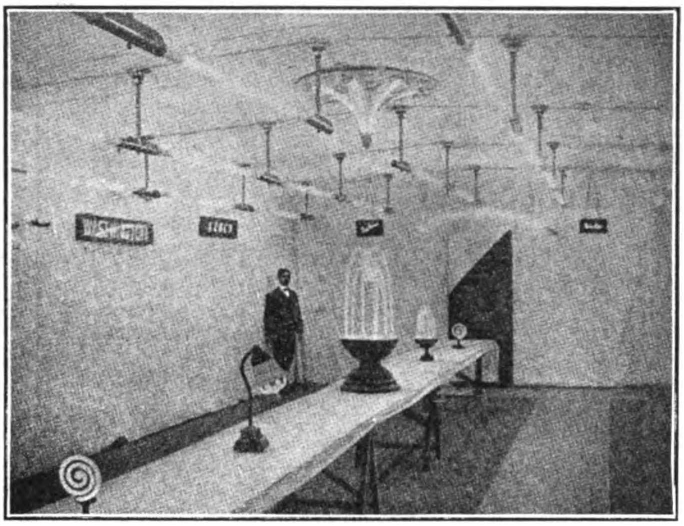


FIG. 13

19, the straight line tubes in the New York Post Office. No light source known today equals in

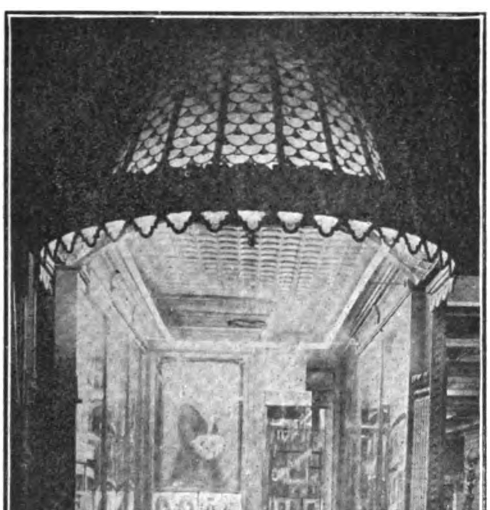


FIG. 14

efficiency a neon tube 1¾ in. in diameter and 200 ft. long. The "long tube" system is theoretically correct in so far as it provides means for generating light at the exact intensity most suitable for the eye; this in contradistinction to the generation of concentrated light at an enormous intensity and temperature that

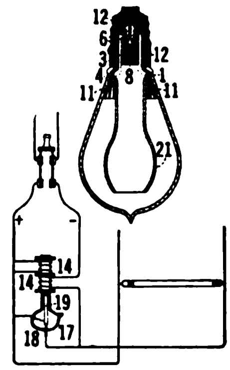


FIG. 15

must, before it can be used by the eye, be either greatly reduced in intensity by means of some kind of semi-transparent or diffusing screen, or widely scattered by a reflector. Fundamentally the first cost of a "long tube" system is less than that of a complete incandescent lamp system and its life is longer with a resulting lower maintenance cost. It is simpler. During 1910-1911, the long tubes in the form of portable artificial daylight windows made their appearance, as shown in Fig. 20.

FIG. 16

Between 1913-1915, several types of small tube lamps, dependent upon the new chemical gas feed principle, were invented and marketed for color matching purposes. The spectrum of this type of color matching lamp will never be surpassed as a standard light by which to judge colors. See Figs. 21, 22, and 23. Simple neon tubes operable from transformers were designed and made in many varieties. Some were equipped with screw lamp bases.

These outfits consume 13 watts and are light enough to be screwed into an ordinary incandescent lamp socket. Lamps of this kind have run without change over 4000 hours.

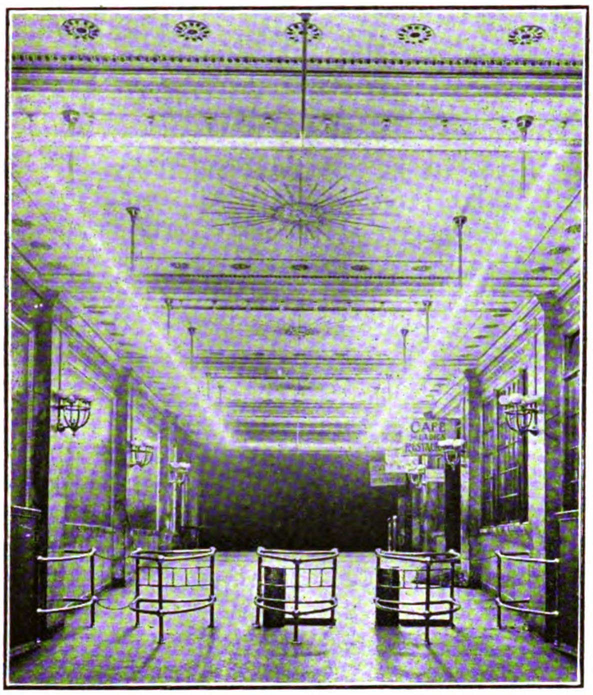


Fig. 17

In the Fall of 1916, there was exhibited the first portable and thoroughly commercial neon tube outfit

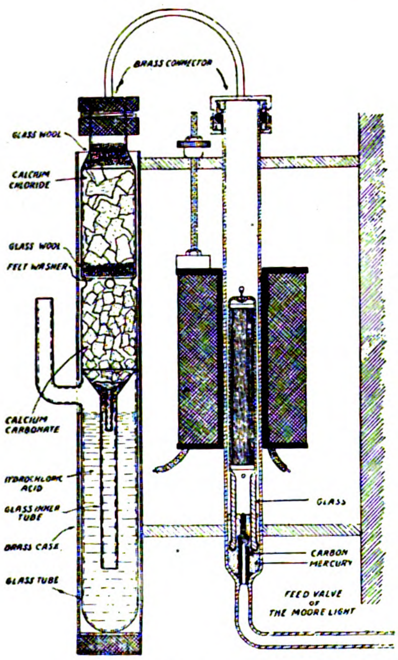


Fig. 18

of high intensity and efficiency operated from a step-up sixty-cycle transformer. It resembles Fig. 21, except that the tube housing is twice as long. The tube was in the form of a hair-pin and had a total gas column length of 101 in. at 7/8-in. diameter. The specific consumption of this type of lamp was 0.74 watts per spherical candle power.

Even this high efficiency can be improved considerably by using purer neon (that is, neon gas that does not contain 25 per cent helium and other impurities) together with a longer gas column of greater diameter. Also the electrode losses can be reduced. But the photometric measurements on this brilliant

Fig. 19

type of tube lamp showed a total of 180 mean spherical candle-power of 2260 lumens with 0.162 ampere passing through the gas column. Simple straight tubes about 1¾ in. diameter and 8 ft. long could be arranged as a continuous line of light and used for

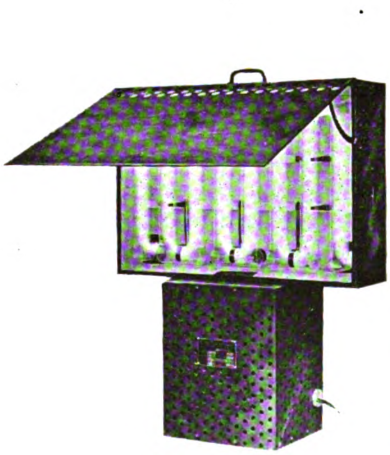


Fig. 20

Fig. 21

the lighting of large interiors or for streets. The initial installations would have great advertising or display worth. The red rays will also be valuable for signaling purposes, etc.

Various alternating-current tube lamps, provided with two similar metal electrodes, were also made to

operate on 220 volts alternating current without a step-up transformer, but they needed a momentary higher voltage to start the gas column discharge which is most simply obtained by short-circuiting a series inductance. The length of the gas column of this type of lamp is too long (about 3 in.) to permit 220 volts to pass any current but it will maintain the discharge, which is positive for an indefinite length

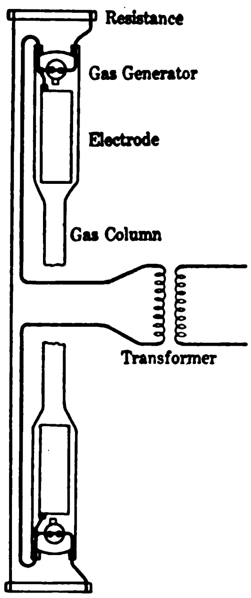


FIG. 23

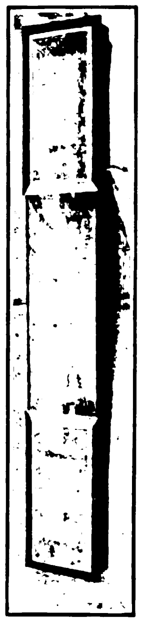


FIG. 22

of time, after once started. The necessity for starting apparatus is an objectionable feature of this particular type of lamp. When the gap or gas column between the electrodes of a tube lamp on 220 volts alternating current is less than about 1¾ in. the light is negative glow.

The direct-current lamp of the type requiring high potential for starting, involves, even when filled with neon gas, a special cathode of mercury of a K-Na amalgam. Still another type of 220-volt direct-current neon tube was started by using an auxiliary current to raise to a high temperature a portion of the cathode. Space will not permit the listing of many other varieties of gaseous lamps.

However it is to the type of lamp that has cold electrodes and is designed to start and operate without using high potential, that your attention is particularly called. As previously stated it is by no means completely developed but it seems to fulfill the original conception of a gaseous conductor lamp without any auxiliaries, for low-potential circuits.

The current of a 220-volt circuit passes through the neon gas and causes it to give light in a manner analogous to the way current passes through a tungsten wire and causes it to give light. No potential raising transformer is required or used. When the particular problem was the production of small units of light, its satisfactory solution by the use of the transformer was commercially impracticable, but it seemed for many years impossible to obtain any light without its use.

Fig. 24, shows a form of this type of lamp, for alternating circuits. Scores of modified designs have been made. It is a novel type of lamp. I hope that many will see in it, with me, the possibilities of a lamp of this kind. In fact diligent inquiry among scientific men has failed to find anyone who did not agree that all theory seemed to indicate the great probability that artificial light of high efficiency will result from the further development of lamps of this kind. The handwriting on the wall seems to unmistakably indicate that to further increase the luminous efficiency of light sources in general, we will need to resort to gaseous radiation, by which means it may be possible to reduce to about one-tenth the energy now required.

Since the ice now seems to be broken on the problem, it is my earnest hope that many of the ablest of inventors will become actively interested, and through the combined knowledge, experience and ingeniousness of all who have studied and worked on gaseous conduction phenomena, the many problems involved will be solved. I believe that a very great deal remains to be learned and discovered.

The lamp shown in Fig. 24 resembles an incandescent lamp in outward form and perhaps is far more simple,

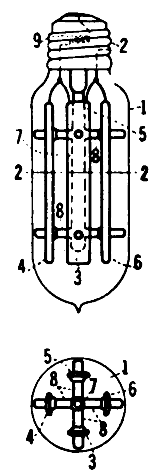


FIG. 24

yet it is not an incandescent lamp. Four electrodes made of aluminum, each 6 in. long, ⅝ in. wide, and $^1/_{16}$ in. thick, are mounted in a 3-in. straight-sided bulb about a common center. A glass bulb, provided with radial arms of glass, supports the electrodes, which have holes in them, and through which the arms extend. The capacity of the solid radiators is objectionable and yet the effect of a solid radiator is approached by radiators, made of very fine meshed netting. An effort was made in designing this lamp, to take advantage of every factor that required minimum voltage so that it would operate on 220 volts or less impressed upon it.

The potential is least (volts per centimeter) for the negative glow. All of the light radiated from this new type of lamp is produced by the negative discharge; —not by the positive column as is the light in all of the long vacuum tubes when in operation from either a-c. or d-c. circuits. All text books and investigators have heretofore considered that the amount of light given by the negative glow in any vacuum tube discharge was so small as to make it entirely negligible as a light source.

An ordinary long tube discharge consists of (a) next to the cathode, the short first dark space (b) the short and not bright negative glow (c) the short second dark space, (d) the long brilliant positive column extending to the anode. But in the lamps herewith described, the positive column has been practically eliminated and substantially the only luminous discharge in the lamp is the negative glow which appears in the form of a velvety glow or corona of yellowish light over the entire surface of the alternating-current electrodes and also a uniform gaseous radiation throughout the entire interior of the bulb.

The lamp shown in Fig. 24, is designed for operation on 220-volt a-c. circuits. At this voltage it uses from the line about 0.11 ampere and 21 watts, but of this amount 3.6 watts at 33 volts is used by an ohmic resistance about 1 in. long placed in the skirt of the lamp base, because due to impurities, principally in the neon gas and the aluminum radiators, a slight blackening may form between them in time, which may cause the lamp to short-circuit.

The finished lamp will probably require no series resistance, but at the present time, the use of such a resistance affords a convenient method of adjusting the total watts consumed, the life or intensity. The specific efficiency of this particular type of lamp is low. When this lamp is consuming 17.4 watts, it gives approximately 1.16 s. c. p., which corresponds to 15 watts per s. c. p. Therefore, the most important problem still to be solved is how to decrease the number of heat waves and increase the number of luminous radiations. When the line voltage was reduced to 135 on this lamp, the light was suddenly extinguished.

The neon used had a helium content of about 25 per cent, but if it had had a nitrogen impurity of a fraction of 1 per cent, the neon lines would have been greatly reduced. The pressure of the gas when sealed off was 3.5 millimeters. The bulb temperature is about 40 deg. cent. but of course is increased when the watts are increased. The color of the light of this lamp is a beautiful yellow.

Some of the important factors given special attention in the designs of this new lamp are:

1. The attempt to use a gaseous conductor of maximum conductivity.
2. Electrodes that are subdivided and of as large a total area as possible.
3. A gas column (discharge gap) as short as possible.
4. The planes of the electrodes of opposite polarity placed parallel to each other.
5. The length of the radiator electrodes greater than the gas column and perpendicular to it.

Since the light is entirely due to negative glow, cathodic disintegration of the electrodes is one of the problems in connection with this type of lamp but it is practically nil when the cathode fall equals its minimum value. It is greater at lower gas pressures and increases as the square of the current, assuming a constant electrode area and gas pressure, but it is not an essential to transmission of current and seems to be largely due to the occluded gases, particularly hydrogen. The bulb blackening is far less with aluminum radiators than tungsten, nickel, copper, etc. Carbon in pure form is difficult to obtain. Iron radiators as well as various radiators combined with fluorescent coatings offer promise.

One of the troubles connected with the use of carbon was the difficulty of removing all of the occluded gases. However, this may be overcome by heating not only carbon electrodes but all other varieties of radiators. Radiators of whatever material should be as pure as possible and be cleansed in the best manner. A combination of light from the glowing gas, and from an incandescent radiator in the same bulb does not seem entirely practical.

This corona type of lamp produces a luminosity that is not due to arcing or even pure discharge phenomena but is due to the glow of light emanating from electrodes or radiators that normally have a temperature below red heat. According to the theory of ionization, the temperature within the negative glow, is higher than within the positive column and the velocity of the negative ion is greater than that of the positive, and this is one reason why the potential required to produce a luminous discharge from a negative pole is less than from a positive, together with the fact that in the negative glow the number of positive and negative ions are about equal.

The exceptional luminous efficiency of neon makes it unique among light sources. Immediately upon the announcement of its discovery in 1898, I proposed its use for lighting purposes. Its great scarcity until recently has made rapid progress impossible. Within the last few days announcement has been made that it can now be bought in almost any quantity and of a high degree of purity. Its luminous spectrum is almost ideally located to affect the eye in a maximum manner. It is a splendid example of selective emission or radiation that eliminates the long and therefore inefficient waves. It does for gaseous conductors just what the Welsbach mantle or the impregnated arc lamp electrode does for heated solids.

The maximum emission is between wave lengths 590 and 650 which is one of the remarkable properties of this gas. It produces over a hundred times as much luminosity for the same watts as does argon for

example. Its dielectric cohesion is 5.6 which is extremely low when compared with air at 419. It has less than one-half the resistance of nitrogen. It is fortunate that the color of the resultant radiation of neon from a positive column is different from that of a negative glow.

Neon gas when used as a positive column of light has a color so reddish that it would be objectionable for

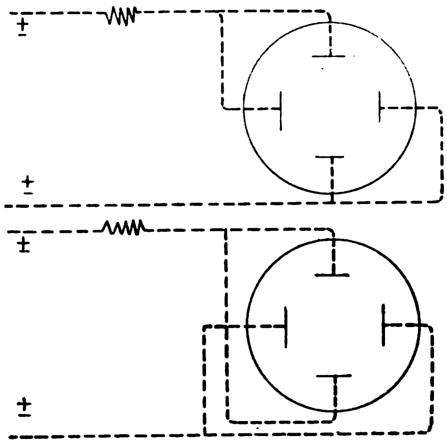


Fig. 25

many purposes but when the same gas is used as a negative glow, the color is yellowish. It has no blue or violet or indigo lines and very few infra red rays. It is four times better as a light producer than the yellow-white light of helium or the violet of xenor, both of which have many infra red rays. The

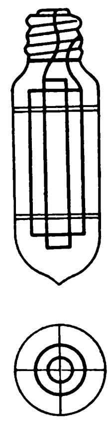


Fig. 26

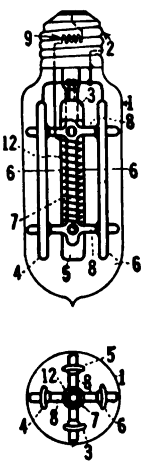


Fig. 27

characteristic crimson of neon has been displaced by a uniform mass of soft yellow light that somewhat resembles the color of a high class oil lamp, or that from the electric incandescent carbon lamp, the intrinsic brilliancy of which is theoretically too great.

The connections of the four radiators are shown in Fig. 25A, but the total flux of light is not very much less when the connections are as per Fig. 25B.

Scores of modifications and varying designs have suggested themselves. For example, such a type of lamp that is suitable for alternating circuits will differ from a properly designed direct-current lamp. But all alternating-circuit lamps will give some light on a direct current of the same voltage. That is, only one of the radiator poles (the negative) will give any light.

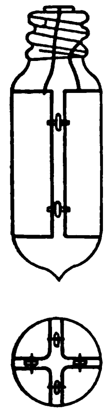


Fig. 28

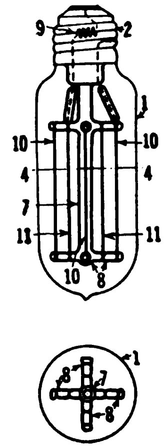


Fig. 29

Therefore, in the case of the lamp shown in Fig. 24, only two of the four radiator plates will be luminous.

The positive poles will remain absolutely dark. This fact is given recognition in the design of the direct current lamp, shown in Fig. 26. The inner cylinder is of sheet aluminum and the outer cylinder is of aluminum netting and made the negative pole.

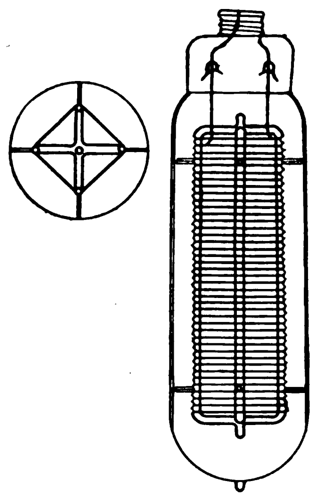


Fig. 30

Fig. 27 which is taken from the United States Patent No. 1,316,967, which was applied for November 30th, 1917, shows the positive electrode in the form of a spiral on the axis of the lamp.

Fig. 28 shows a very simple lamp for alternating circuits that is constructed by inserting into a 3-in. straight-sided glass bulb four right angles made of aluminum netting, of 0.052 wire having a mesh of eight wires per inch. Each right angle is 5 in. long. Eight glass buttons or spacers keep all portions of these four angles at a uniform distance of $^3/_{16}$ in.

from each other, and they are all held in place by the walls of the bulb.

Just as a final mechanical form for the major designs of the tungsten lamp was arrived at, so also will doubtless be the case with lamps or tubes based on the corona principle. These lamps should be so designed mechanically that a maximum amount of the light that is generated has free exit or is reflected in the best manner.

Fig. 29 has a construction that closely resembles that of a standard tungsten incandescent lamp, and Fig. 30 shows wire electrodes wound parallel to each other on a glass drum. Fig. 31 shows such a lamp in the form of a tube.

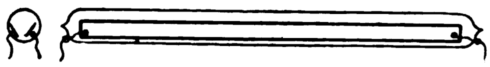


Fig. 31

The dozen most important factors involved in the design of these lamps should be examined theoretically and a definite conclusion reached concerning each one, so as to determine definitely its possibilities.

Some of the important variables are:

The gas pressure, for (a) efficiency, (b) life.

Electrodes; material, form (wire) and area, best suited for a definite voltage, life, wattage, intensity and efficiency.

The exhaust programme.

The length of the gas column, that is distance between radiators of opposite polarity.

Volume and shape of the bulb.

When the gas pressure is too high (about 10 millimeters) no light appears but at 6 milliameters it consists of a velvety or luminescent glow that closely envelopes the radiators but extends further and further from them as the pressure grows less until it fills the entire bulb with a suffused glow, which, however, becomes thinner and less luminous when the pressure is still further reduced.

It seems advantageous to subdivide the radiator of each negative pole. The lamp made as shown in Fig. 32, shows that far more light is generated between such subdivisions than between areas attached to opposite poles.

It is apparent that it is very desirable to produce a brighter lamp. Photometric measurements of lamps constructed as in Fig. 30, showed 2.59 spherical candle power on 220 volts alternating current. The higher the voltage, the easier is this problem. Therefore, perhaps it would be best to first develop a lamp for the commercial 500-volt circuits. When the voltage is raised abnormally on most of these lamps they will arc destructively even though the air gap is large. Often times there seems to be less tendency to this destructive "ball discharge" arcing when the air gap is small, than when it is large, because then the ohmic series resistance can be greater. The lamp as shown in Fig. 24, has a discharge gap of 5/8 in. but in other lamps it varies from 1/32 in. to one inch.

The lamps that give the most light on 110 volts are those whose radiators were made of wire of small diameter and small total area as shown in Fig. 29.

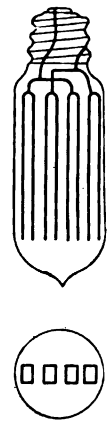


Fig. 32

TABLE I—ALTERNATING CURRENT

Lamp Nos.	Line		Lamp		Lamp s. c. p.	Lamp w.s.c.p	Line watts	Line w. per s. c. p.	Series w.
M.	V.	A.	V.	W.	A-C.	A-C.	A-C.	A-C.	
547	155 min.								
	164	0.03	149	5.	0.234	21.	4.5	24.	500 w.
	184	0.062	148	6.5	0.32	20.5	8.5	26.5	
	221	0.105	168	15.5	0.594	26.	21.	35.5	
	240	0.127	177	20.	0.780	25.5	28.	36.	
	264	0.16	184	24.5	1.04	23.5	37.5	36	
595	135 min.								300 w.
	166	0.045	153	3.9	0.258	15.	4.5	17.	
	181	0.06	162	7.	0.535	13.	8.1	14.	
	220	0.11	187	17.4	1.15	15.	21.	17.	
	239	0.14	197	23.3	1.77	13.	29.	16.	
	265	0.18	211	32.9	2.44	13.4	42.6	17	
594	127 min.								300 w.
	167	0.045	153	4.4	0.392	11.2	5.0	12.	
	182	0.075	159	9.3	0.635	14.7	11.	17.	
	220	0.135	180	21.	1.24	17.	26.4	21.2	
	240	0.17	189	27.8	1.7	16.	36.5	21 4	
	265	0.215	200	37.2	2.4	15.	51.	21.2	
430	220	0.13	155	17.	0.715	23.5	26	34.	500 w.
605	220	0.11	188	16.7	0.897	18.5	20	22.	300 w.
609	220	0.245	195	53	1.825	29.	58	32	100 w.
600	220	0.095	172	14.1	0.715	19.8	18.6	26	500 w.
674 etc.									
647	220	0.185	164.5	24.5	0.870	28.	34.5	39.	300 w.
270	220	0.205	179.	29.	1.047	27.	37.5	36.	200 w.
669	220	0.135	193.	15.9	0.645	24.	19.5	30.	200 w.
675	220	0.085	126.5	19.	0.601	31.	16.5	27.	1100w.
673	220	0.22	176.	30.3	0.847	35.	40.	47.	200 w.

Photometric data of various types of these corona lamps have been obtained by the use of an 80-in. sphere. Color corrections were made by the following procedure:

1. Hold Moore lamp at 220 volts and adjust comparison lamp to Moore lamp color.

2. Set galvanometer on zero and maintain comparison lamp at above color.

3. Adjust Mazda "B" lamp to comparison lamp color and note voltage.

4. Ascertain horizontal candle power of Mazda "B" lamp at above voltage.

5. Horizontal c. p. of Mazda "B" lamp x 0.785—s. c. p. of Mazda "B" lamp.

6. Read Mazda "B" lamp and all d-c. or a-c. Moore lamps against comparison lamp as set.

Table II—DIRECT CURRENT

Lamp Nos.	Line		Lamp		Lamp s. c. p.	Lamp w.s.c.p	Line watts	Line w. per s. c. p.	Series w.
M.	V.	A.	V.	W.					
547	165	0.017	156.5	2.66	0.158	16.	2.8	17.8	500 w.
	220	0.066	187	12.3	0.444	27.	14.5	32.7	
	265	0.124	203	25.1	0.880	28	32.8	37.3	
595	165	0.013	161.0	2.0	0.178	11.7	21.1	12.1	300 w.
	220	0.072	198.4	14.2	0.792	17.8	15.8	20.	
	265	0.134	224.	30.	1.88	16.	35.8	18.9	
594	165	0.014	160.8	2.2	0.178	12.3	2.3	12.9	300 w.
	220	0.061	201.7	12.3	0.663	18.7	13.4	20.2	
	265	0.13	26.1	33.9	1.53	22.	34.4	22.5	
605	165	0.015	160.	2.5	0.217	11.5	2.6	1.22	300 w.
	220	0.078	196.6	15.2	0.787	19.	17.1	21.8	
	265	0.146	221.	32.	1.48	22.3	38.7	26.	
609	220	0.16	204	32.4	1.48	21.5	35.	23.5	100 w.
430	219	0.105	166	16.2	0.796	22.5	21.9	27.4	500 w.
600	220	0.04	198	8.	0.387	20.5	8.8	22.5	500 w

7. Multiply Moore lamp readings by ratio of Mazda "B" reading to Mazda "B" s. c. p.

The tabulations of Table I show first the performances of four lamps constructed approximately as shown in Fig. 24 on alternating current, and then follow the test data of several lamps of varying constructions.

The tabulations of Table II show most of these lamps when operating on d-c. circuits, under which circumstances of course, but one pole gives any light.

It is only safe to consider these data however as indicating very broad generalizations because no two lamps have been made alike, even as regards their mechanical construction, and they also differ as regards the purity of the gas and its pressure, the exhaust programme, etc. There were also encountered difficulties as regards the photometrical and electrical measurements, for example, when such a lamp is consuming less than two watts, yet the amount of light seems considerable to the eye in a dark room.

Nevertheless, I believe that complete and exact specifications should be determined upon for an ideal lamp of this nature entirely independent of its comparative relations to other and seemingly far superior forms of artificial light.

Some of the conclusions that may be drawn are as follows:

1. Efficiency of these lamps is about the same whether operating on a-c. or d-c. circuits.

2. Efficiency is about the same on a-c. circuits over a wide voltage range.

3. Efficiency is about the same on a-c. circuits over a wide range of intensities.

4. S. c. p. varies approximately with the wattage on either a-c. or d-c.

5. That the lamps with a reasonably pure neon color were not as efficient as those in which gas impurities made the color whiter.

6. The general lamp performance is not very sensitive to wide variations in the length of the gas column or gap.

7. The same lamp equipped with the same resistance and operating at the same voltage takes a considerably higher line wattage on a-c. than on d-c., which doubtless is principally due to the light radiating area being double.

8. The c. p. is greater with radiators of large area.

9. The power factor of these lamps is about 85 per cent.

These lamps demonstrate that useful gaseous conductor light, that, to say the least, has advertising value, can now be produced in a simple manner from ordinary commercial circuits. Special uses will be found for such lamps for example as polarity or potential indicators. Since the internal parts are all below red heat gas explosions will not be caused by bulb breakage. Gaseous light, due to electrical agitation has, to a limited extent, been emancipated from all necessity for a heretofore ever present high potential either for starting or normal operation. The basic conception of using a gas to supplant the heated filament in an ordinary lamp seemed wholly impossible, yet, this new type of lamp makes it at least a partial reality. It constitutes an advance in that it adds to our knowledge of a very little developed subject. A new epoch in the history of gaseous conduction lighting has been reached. It is my hope that the great cause of new and better lighting methods in which my deep interest has been centered for years, may be spurred to rapid advancement in a new direction that gives promise of reward to an unlimited number of worthy investigators and inventors.

Installation and operation of electric machinery for handling all materials in manufactories, depots, terminals and other commercial places offers the greatest potential field for development in the industry today, stated Zenas W. Carter, manager of The Material Handling Machinery Manufacturers' Association, of New York City, in his address before the fourth general session of the N. E. L. A. Convention.

Only five per cent of the potential demand for handling machinery has been met, and, since 85 to 90 per cent of all material handling machinery is electrically operated, the opportunity may be realized.

High wages, labor shortage and need for speeding up of production are given as the three cardinal reasons why every effort should be made to develop this field as speedily as possible.—*N. E. L. A. Bulletin.*

Technical Committee Reports

ANNUAL REPORT OF THE ELECTROCHEMISTRY AND ELECTRO METALLURGY COMMITTEE

To the Board of Directors.

THE chairman of the Electrochemistry and Electrometallurgy Committee for the year 1917–1918 suggested to the Board of Directors of the American Electrochemical Society that it should approach the A. I. E. E. with the idea of forming a joint committee to consider matters that were of common interest to the two societies. Such a committee could consider papers which might be of importance to both societies, could bring to each society's attention matters of common interest and make arrangements for occasional joint meetings. The result was that the Board of the American Electrochemical Society appointed Messrs. Fink, Parmelee and Schluederberg "to cooperate with" this Committee.

Nothing was done in this matter in the year 1918-1919; but this year it was taken up again with the result that a joint meeting of the A. I. E. E. and the A. E. S. was held in Boston April 9th, 1920. The meeting was successful, the combined registration amounting to about 425, with the result that the seating space of the rooms used for meeting was somewhat overtaxed.

It is believed that the occasional holding of joint meetings with the A. E. S. similar to that held this year is desirable and it is suggested that the plan be followed up next year when an even more successful joint meeting might be held. The weak point of the April meeting was the failure to print in advance some of the papers presented at the meeting by members of the A. I. E. E. The blame for this rests with the chairman of your committee who had not provided for his unforseen detention in Europe during the first part of the year, with the result that sufficient time was not given to authors to prepare their papers before the meeting. The printing of the papers in advance of the meeting is important so as to stimulate discussion and the exchange of views between the members of the two societies which have so much ground of common interest.

FRANCIS A. J. FITZGERALD, *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON ELECTRICAL MACHINERY

To the Board of Directors.

THE Committee on Electrical Machinery placed before itself the aim to cover as nearly as possible the range of work in which there had been changes of importance which had not yet become a matter of record in the TRANSACTIONS of the Institute.

The Committee joined with other committees in the presentation of papers at the Midwinter Convention on the general subject of super power stations for the eastern coast states. This subject will receive renewed attention from time to time.

The polyphase alternating current commutator motor for variable speed operation received comprehensive treatment in two papers, one by B. G. Lamme, presented before the Schenectady Section, and the other by John I. Hull, to be presented at the Annual Convention.

The subject of temperature measurements in large alternating current generators and allied questions received a complete and exhaustive treatment in four papers to be presented at the Annual Convention. Rationalization of temperature measurements and uniformity of policy have been established as a result of these papers and of the investigations which led up to them.

A mathematical paper by R. E. Gilman discusses the losses due to eddy currents in stranded conductors embedded in slots, thus carrying on further the fundamental work begun by A. B. Field.

A symposium of papers on the design and the operating characteristics of welding machinery has been arranged for the Annual Convention so as to make a record in the TRANSACTIONS of the progress made in this important direction.

In presenting this brief report, the Chairman desires to point out that he has considered it the essential function of his Committee to trace, through the papers solicited and the meetings arranged, the progress of the art which it was desired to record. Thus it is unnecessary to deal again here with the subject matters comprehensively presented in the papers.

In conclusion, the Chairman wishes to thank the members of his Committee for their support and co-operation.

B. A. BEHREND, *Chairman*

ANNUAL REPORT OF THE PROTECTIVE DEVICES COMMITTEE

To the Board of Directors.

EARLY in the year the Protective Devices Committee appointed a number of sub-committees to investigate, study and report on various subjects and these are discussed in some detail in the following summary.

SUB-COMMITTEE ON TERM, "INSTANTANEOUS RELAY"

E. E. F. CREIGHTON, *chairman*

This Sub-Committee resulted from the criticism of the term "instantaneous" as applied to a relay, it being contended that the term did not properly describe the device. A number of other terms were suggested of

which the term "quick acting" appeared to have the preference. On account of the wide diversity of opinions among the members of the committee on the subject, no definite recommendation has been made, and it was agreed that the Chairman of the Sub-Committee would summarize the various opinions on the subject and submit them for publication in the JOURNAL.

SUB-COMMITTEE ON SCHEMES OF RELAY PROTECTION

P. H. CHASE, *chairman*

Following the recommendation in the Report of the Committee last year, a number of letters were written to the executives on a selected list of operating companies, and about thirty-five replies have been received from companies who were willing to cooperate in the work assigned to this sub-committee, and one of their engineers delegated as the correspondent on the subject. Questionnaires regarding schemes of relay protection have been forwarded to these correspondents. The United States and Canada has been divided into six geographical sections and each section has been assigned to a member of the sub-committee who is with an operating company in that district. These members are charged with examination and classification of replies received and with distribution of the information to the other members of the sub-committee. It is felt that the work of the sub-committee to date has been very largely of a preliminary nature and that its value will be more apparent later in the year.

SUB-COMMITTEE ON OIL CIRCUIT BREAKERS AND SWITCHES

H. R. WOODROW, *chairman*

This Sub-Committee is cooperating with similar committees of the National Electric Light Association and the Power Club, and is securing information on the subject from a limited number of the larger operating companies. There has not been sufficient time since the request for information was issued, to secure answers from the various companies and to summarize the results. The subject of high-tension fuse protection has also been referred to this Sub-Committee.

SUB-COMMITTEE ON SYSTEM DISTURBANCES

D. W. ROPER, *chairman*

It was the opinion of a number of members of the Committee that the serious system disturbances experienced by the operating companies were due in a large measure to the defective action, or perhaps the absence, of suitable protective devices, and that a study of such disturbances might indicate the lines along which the future work and study of the Protective Devices Committee should properly be directed. The members of the Sub-Committee are interchanging information on this subject and in recent months have been somewhat embarrassed by the amount of data available. An unusually large percentage of the larger operating companies have experienced severe system disturbances and in some cases the behavior of the protective devices was an important factor in the disturbances. The Sub-Committee is now endeavoring to formulate some standard method of reporting on such matters, so that the reports can be properly condensed and summarized and be made available for the purposes of the Protective Devices Committee.

SUB-COMMITTEE ON REACTORS

F. E. RICKETTS, *chairman*

In the last few years there has been a marked improvement in the design of reactors such as, methods of winding to reduce eddy currents, improvements in structure to increase the insulation strength, and to work the copper to the best advantage. In some cases this improvement in design has been taken advantage of to reduce the size of the reactor so that the coils of today are small when compared with those of equal rating built a few years ago. This, however, is not a feature that should be carried to extremes as the current limiting reactor is, fundamentally a protective device and this function should be fully recognized in its development. Every effort should be toward the perfection of the design to avoid failure of the device itself and at the same time avoid the reduction of any of the protective features.

The application of reactors has been reviewed at different times in papers presented before the Institute and various schemes of connection have been proposed; but there is still some difference of opinion as to the proper place to insert reactors to obtain the best results, and there are many factors entering into this question. Each application requires a separate study but in general the best protection for the service is obtained by installing the reactors in individual feeders, and this is the practise followed by most companies provided the necessary space is available. However, some engineers prefer to sectionalize the system by inserting reactors in the bus, but when this is done, consideration should be given to the possbility of increasing the chance of the different sections getting out of synchronism which becomes very much of an operating menace where the amount of reactance in the circuits of the generators is much greater than that necessary to give the greatest synchronizing power.

SUB-COMMITTEE ON RESISTORS FOR USE WITH POTENTIAL TRANSFORMER FUSES

R. N. CONWELL, *chairman*

One of the larger companies in New York has made some elaborate and complete short circuit tests on potential transformer fuses installed with and without protective resistors in series. Following these tests a number of companies in and around New York have adopted the standard practise of installing protective resistors in series with the potential transformer fuses which are connected to their high-tension buses for the purpose of limiting the current, and in this manner

preventing damage to apparatus or interruption to service which had previously occurred. A summary of the results of the investigations, with the practise of the several companies is being prepared for submission to the Publication Committee for use in the JOURNAL. A canvass by the Chairman brought forth the information that certain other companies are using a different type of fuse which has given excellent results in service, and which does not require the use of a protective resistor in series.

PRIMARY CUTOUTS FOR LINE TRANSFORMERS

This subject was discussed at some length in the meetings of the Committee. It was the opinion of a number of the members of the committee that are connected with operating companies that the development of primary cutouts for line transformers had not kept pace with the development of the transformers themselves. One company reported they had considerably more trouble originating in the primary cutouts than in the transformers which these cutouts were intended to protect. Several of the larger companies install the larger sizes of overhead line transformers and all sizes of subway types of transformers in manholes without any primary cutout as their experience indicates that they have fewer interruptions in this manner than they would if they attempted to use cutouts with these transformers. It is the opinion of the members of the Committee that if the larger manufacturing companies would devote as much engineering skill to improvements in primary cutouts as they do to improving the design of line transformers, this difficulty which is one of long standing, would very quickly be eliminated.

During the discussion of the subject of primary cutouts it was brought out that one of the largest companies had, some years ago, abandoned the use of all types of cutouts or lightning arresters which were enclosed in an iron case. This was found necessary on account of the troubles with these devices during rain storms and wet snow storms, and that the difficulty had increased with the size of the generating or transforming units which supplied the current to the lines on which these devices were installed. During the past year another large operating company has taken exactly the same action and for the same reason. The Committee therefore, recommends that operating companies take note of this situation as with the increase in the size of their generating and transforming units they will ultimately be called upon to take similar action and they should, therefore, investigate types of such devices without the metal enclosing case with a view to its adoption for their future work.

During the year the Committee has undertaken to make investigations which will not be completed during the fiscal year. The Committee members who are taking an active part in this work all feel that the work is not only of particular interest to the members of the sub-committees, but should ultimately result in something of value to the Institute. It is recommended that the investigations of these subjects be continued next year, and that the members of the sub-committees who have been actively engaged in these several investigations be continued on the Protective Devices Committee during the ensuing year.

D. W. ROPER, *Chairman.*

ANNUAL REPORT OF COMMITTEE ON INSTRUMENTS AND MEASUREMENTS

To the Board of Directors.

THE Instruments and Measurements Committee submits the following report covering its own activities during the past year and the developments and progress in that part of the electrical field covered by its title.

A considerable number of papers was arranged for during the year and at the Mid-Winter Convention in February, one morning session, one afternoon session and part of a second afternoon session were assigned to this Committee. A most interesting and valuable group of papers was presented. The sessions were very well attended and the discussion was limited only by the available time.

The papers presented at the sessions referred to above are as listed below:

1. "Measurements of Projectile Velocities" by Dr. P. E. Klopsteg and Major A. L. Loomis.
2. "A New Form of Vibration Galvanometer" by Mr. P. G. Agnew.
3. "Precision Galvanometer for Measuring Thermo E. M. Fs." by Messrs. T. R. Harrison and P. D. Foote.
4. "Notes on Synchronous Commutators" by Professor J. B. Whitehead and Mr. T. Isshiki.
5. "Oscillographs and Their Tests" by Professor A. E. Kennelly and Mr. A. A. Prior.
6. "The Accuracy of Commercial Electrical Measurements" by Mr. H. B. Brooks.

Without entering into a complete review of all the papers or the discussion, brief mention should be made of the paper on the Check and Calibration of Oscillographs and the paper on the Accuracy of Commercial Electrical Measurements. The oscillograph is rather generally used as a means of practically ultimate analysis of electrical functions and phenomena, and the paper provides the means of checking the functions and characteristics of the oscillograph itself. The contribution to the papers of the Institute entitled "The Accuracy of Commercial Electrical Measurements" is a most thorough and comprehensive analysis, review and statement of the characteristics and limitations of the many commonly used electrical instruments. This paper will, without doubt, serve as a ready reference for many years and should be of value to many engineers in other than actual testing

work. It covers in a thorough and intelligent manner the errors that may be expected in the use of various instruments under various conditions.

The definition of power factor in polyphase circuits is a matter that has been active and of interest from many angles throughout the past year. While it has been the direct work of a Special Joint Committee of the N. E. L. A. and the A. I. E. E., its work falls within the general purview of this committee and a brief mention in this report seems entirely proper The Special Joint Committee canvassed the manufacturing, operating, scholastic and purely engineering branches of the electrical industry and prepared a report of its findings. It was intended to have this report presented at the Mid-Winter Convention last February. It was impossible, however, to analyze and intelligently condense in the form of a report, the volume of material received. It was decided, therefore, to have the report ready for presentation at the Summer Convention of the A. I. E. E. and to have a session assigned to the general subject. Arrangements will be made for discussion by various interested individuals to present the point of view of various interests affected by the settlement of the question. It was hoped that this method of procedure would provide an adequate form for the use of the many interested individuals and permit the ultimate acceptance of a satisfactory solution of the question.

Your committee has surveyed the field of manufacture of instruments and measuring devices and finds in general a few reports of new developments, some reports on standardization and adaptation to commercial usage of the designs dictated by the war and practically unanimous reports from all of the manufacturers of extreme difficulty in contending with the shortage of material and labor turnover in the production of the standard and accepted lines of apparatus.

The various companies manufacturing watthour meters and demand devices, practically all report the completion of experimental models, finished designs or actual production of devices for measuring kv-a-hr. and demand devices for measuring the demands of kv-a. and kw. and power factor. These various devices may make the measurements separately or simultaneously on a single record. Further there is a steady continuation in the development and standardization of maximum-demand devices to complete the series of devices suitable for easy adaptation to d-c. watthour meters, a-c. watthour meters and various frequencies.

Aside from the adaptation to various types of meters there is the continuation of the development providing devices actuated on the time basis, either on spring driven clocks, spring driven clocks electrically wound or motor driven clocks.

The Warren motor referred to in last year's report of this committee continues to be developed in a most satisfactory manner. It is being used for the control of frequency on generating systems through the master clock. It is also being installed in many forms of graphic and recording instruments used for various purposes throughout the stations of generating and distributing systems.

In the field of indicating instruments, both for direct- and alternating-current use, it is found that the designs which were developed particularly for war purposes, have been modified sufficiently to meet the regular demand and there are now available lines of both switchboard and portable types of instruments that were not available two or three years ago. These instruments are in general of a very satisfactory type and serve a very useful purpose in providing other sources of supply of instruments which did not exist some years ago.

The greatly increased activity in the measurement of high frequencies used in wireless work caused the development of vacuum thermal converters. These devices serve very satisfactorily for other purposes than for wireless work inasmuch as they permit the precise measurement of extremely small values of alternating current, a field of measurement which has not until recent times been covered by other than laboratory instruments.

In canvassing the field of telephone and telegraph engineering for instruments and measurements, the committee finds in answer to inquiry practically nothing to report, but mainly the continuation of developments which were started during the war period and previously reported.

Reports from those companies specializing in the manufacture of laboratory and precision instruments indicate a very valuable development of this type of instrument for certain special as well as general purposes. The line of development has been to produce on a commercial scale automatic precision electrical instruments, either of the indicating or the graphic type. Wheatstone bridges and potentiometers are normally considered as indicating instruments or devices manually operated by means of dial switches or plug contacts. One of the companies manufacturing this type of apparatus reports the development of an automatic potentiometer and an automatic Wheatstone bridge, both used for recording or controlling processes or a combination of the two. These automatic equipments are supplied for the control of chemical and electrochemical processes and some installations of these are in actual use. For chemical and electrochemical work the automatic Wheatstone bridge can be operated on a commercial 60-cycle a-c. circuit and a special a-c. galvanometer has been especially developed for this equipment.

Two of the important applications of the a-c. Wheatstone bridge equipment, are the recording of surface condenser leakage in power plant operation and the controlling of the finish point during the evaporation process in plants making condensed milk. The

potentiometer equipment is also used for accurately recording and even controlling the acidity and alkalinity of solutions through the measure of the potential between two electrodes immersed in the liquid.

The recording or indicating potentiometer when used in connection with thermocouples produce a very satisfactory and accurate record of temperature. The measurement of temperatures is, of course, directly related to design and operating requirements of electrical apparatus and these devices serve very satisfactorily indeed to analyze the daily or weekly cycles of thermal performance of cables, transformers, turbine generators or in fact any of the various commonly used types of apparatus in generating and distribution systems.

S. G. RHODES, *Chairman.*

ANNUAL REPORT OF THE TELEGRAPHY AND TELEPHONY COMMITTEE

To the Board of Directors:

FOLLOWING out the plan adopted last year as to the form of annual report to be submitted by the committee the following report includes references to technical progress only. The report is made up of contributions forwarded by each member of the committee.

STANDARDIZATION

During the past year considerable progress has been made in standardizing telegraph and telephone practises of the railroads of this country and Canada. Committees composed of representatives of the railroads, the commercial telegraph and telephone companies, and various manufacturers of apparatus, have prepared specifications for materials, apparatus and methods which, while conforming to the generally accepted standards in each case, include special features adapting them to railroad requirements. It is expected that these specifications will be formally adopted by the American Railroad Association in the near future, and that the desired approach to uniformity of practise will soon follow.

TOLL LINE CONSTRUCTION

Toll circuits may be composed of either open wire on pole lines, aerial cable, or underground cable. Any one of these will give high grade transmission when improved equipment and methods of operation are used. Therefore, the tendency in toll line construction is to build plant which will be most economical and at the same time reduce the cases of interference to service from storm breaks and various other troubles to a minimum.

Underground cables properly installed and maintained are open to the least interference to service. However, it is not economical to place underground construction unless more than two full-size cables are required. Generally, underground cables cannot be justified except between the larger centers and their surburban sections.

Aerial cables are liable to less interference than open wires, but economy restricts their use largely to cases where the existing number of circuits and the rate of increase require extensive rebuilding, or additional pole lines to continue on an open wire line basis. Where the number of circuits will not justify aerial cable, open wire circuits must be constructed and maintained.

UNDERGROUND CABLE CONSTRUCTION

No radical changes have recently been made in engineering or construction methods involved in connection with laying of underground cables. The maximum size of cable used contains 1200 pairs of No. 24 B. & S. gage wires. Experimental work is being carried on for the purpose of increasing the number of wires without increasing the diameter of the cable sheath.

Troubles in underground cables have been due in part to disorderly arrangement of cables in manholes and the manner in which the splices were made. Great stress is now being laid upon the importance of having the manholes in good condition, supporting the cables in an orderly manner, and making splices with extreme care. The cost of labor required for installing underground cables is relatively small compared with the total cost of the cable in place, and therefore it is felt that all reasonable efforts should be made to install and splice the cables in such manner as to reduce the cable troubles to a minimum.

INDUCTIVE INTERFERENCE

The Railroad Commission of the State of California has recently published a comprehensive work entitled, "Inductive Interference," in which is given a large amount of technical information gotten together by the Joint Committee on Inductive Interference, which investigated this subject in California over a period of about five years. This work makes available to interested parties a great deal of information of fundamental importance.

The activity in both the power and the communication fields since the war, has demanded renewed close attention to the study of inductive interference.

The growing use of electric arc furnaces which usually produce great distortion of wave form has given rise to serious new problems in noise interference prevention.

The methods of overcoming interference with communication circuits from abnormal conditions on adjacent power circuits have not been so well developed as the methods of overcoming disturbances from the normal operation of power circuits. Constant increase in the amounts of energy carried by power circuits has also made these problems more difficult. Especial attention must be given, therefore, to this phase of interference, particularly along the lines of limiting

the number of abnormal conditions, reducing the length of time in which the circuits are abnormal and in limiting the magnitude of unbalanced power currents during such abnormal periods.

Information on the subject of interference from electric railways has been increased by two or three important investigations, but is still far from complete.

Printing Telegraph Tendencies

While the invention of systems of printing telegraphs has been active substantially since the introduction of Morse's telegraph in the year 1844, the use of printing telegraphs on a commercial scale in America—aside from stock and news ticker systems—has been extensive only since about the year 1900. During the past twenty years improved printing telegraph systems have been extensively applied in moving traffic over trunk circuits where the volume of business is heavy and continuous. On the lines of the Western Union Telegraph Company practically 80 per cent of the trunk line traffic is so despatched. The Postal Telegraph-Cable Company, on the other hand, makes no use of printing telegraph systems at the present time. On railroad telegraph lines printing telegraphs are used also to a large extent.

The next stage of development—now very likely close at hand—is the application of printing telegraphs to wider uses and to circuits having a much lighter than trunk line traffic load. Extending to light-load circuits the use of printer systems makes simplicity of operation, low first cost, and low maintenance cost of first importance.

With the object of meeting the requirements for simplification work is now under way with tape printing devices. Also, it is probable that two or three other systems of simplified telegraph printing will be given trials in service before long.

Radio Signaling

The year 1919 has seen the application of discoveries and inventions which were necessarily veiled in secrecy during the years of war. Under stimulus of war necessity remarkable progress was made in the application and extension of the known principles of the art, standardization of radio apparatus and of its quantity production and use. These advances were made possible by the cooperation of industrial companies, their engineers, and engineers and scientists with academic connections. The efforts of these individuals or groups were ably coordinated and stimulated by the military and naval branches of the Government.

Progress during the past year has been more in the nature of a consolidation of the scientific advances of the war time than in the nature of an entry into new fields. The entire art of radio communication now stands on a firmer basis, with a greatly enlarged personnel of trained engineers and research investigators.

Radio telephone communication was maintained between the seat of Government and the steamship George Washington, on which President Wilson made his European voyages. In these demonstrations the radio station at New Brunswick, N. J., was used.

The guidance by radio of airplanes engaged in peace-time activities is well illustrated in the directing towards landing places of the planes of the Post Office Department. Communication with planes on long voyages was accomplished in the memorable voyage of the N C-4.

High-speed radio telegraphy has been greatly accelerated by the use of the Hoxie recorder and the Alexanderson magnetic amplifier. Direction-finding by radio compasses and its corollary of directive-receiving has been placed upon a firm scientific basis.

The possibility of selecting signals with reference to their direction has been successfully applied by Weagant, Wood, Taylor, Alexanderson, and others, to the selection of desired signals and the discrimination against atmospheric disturbances and signals of foreign stations. These principles have also permitted engineering advances in duplex, or two-way operation of pairs of stations, and in increased possibilities of multiplex transmission and reception. Knowledge and experience along the lines of duplex and multiplex operation has given added interest to the questions of regulation of wave length, range, and of the effect upon radio development of legislative action.

In the manufacturing field there has been progress not only in standardization of apparatus and in better performance, but also in the production of equipment for high-power continuous-wave stations; compact and simple apparatus for medium-power stations and short-range sets suitable for amateur use.

The withdrawal of military restrictions has resulted in a stimulus to amateur operation. By the encouragement of amateurs and of the research departments of the universities and engineering schools, the art should attract additional workers and provide for its future the necessary increase in an enthusiastic and well-trained personnel.

Automatic Telephony

During the past year there was begun a movement which may become general looking to the converting of manual telephone exchanges to automatic operation. The same movement is said to be under way in foreign countries. From the mechanical standpoint there were no outstanding improvements in automatic telephony brought into public use. Progress took the form of a general refinement of details necessary to meet operating conditions.

DONALD MCNICOL, *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON TRANSMISSION AND DISTRIBUTION

To the Board of Directors.

THE Committee on Transmission and Distribution submits the following report for the year 1919-1920:

General

Early in the year the Board's Committee on Technical Activities suggested that it might be advantageous to change somewhat the character of the Annual Reports of the Technical Committee so that each of these reports would become an authoritative source from which could be obtained a complete resumé of developments in its particular field.

This matter was thoroughly discussed at a meeting of the Technical Committee Chairmen, who were of the opinion that it would be inadvisable to take such a step

The chief objections to the plan may be summed up as follows:

1. The preparation of a really complete and authoritative annual resume by each Technical Committee would require a great deal more time than could possibly be devoted to it by the Committee members.

2. Several publications prepare annual digests of developments and an attempt by the Institute to prepare similar statements would be more or less in the nature of duplication.

3. The preparation of a summary by the Committee instead of the present method of reviewing papers presented, would eliminate the personal element. This might tend to take away the incentive which now exists for the preparation of papers, as under present conditions, the preparation of papers is solicited, and when abstracted for the Annual report, full credit is given to the author.

It therefore seems that the advance in the art is best recorded by the present methods, and that those who desire a summary of developments, obtain this summary in a more accurate form than would be possible if the Committee's Annual Report were to deal in generalities.

During the year your committee in conjunction with the National Electric Light Association Underground Systems Committee, formed a joint Sub-committee on Cable Specifications.

This Sub-committee, after a number of conferences in which practically all the cable manufacturing companies were represented, completed its standard specification for paper insulated lead covered cable. This specification, which is accompanied by an appendix giving very complete notes explaining the various clauses, is printed in full as part of the report of the Committee on Underground Systems of the National Electric Light Association. The specification is also printed in pamphlet form for general distribution among cable engineers.

As a result of this standardization, cable manufactured under these specifications will be of the first quality and in accordance with the latest and best practise.

In addition to the work on preparation of cable specifications, this Joint Sub-committee is also preparing data and carrying on investigations of the dielectric losses in cables, relation of heating of cables to their load-carrying capacity, and such other information as is essential to the proper operation of underground cable systems.

In this connection, the Sub-committee has plans under way for the construction of an experimental conduit line about 200 feet in length. With the facilities offered by this experimental line the following phases of the problem will be investigated:

1. Relative temperature drops taken up by the cable insulation, air surrounding the cable, duct walls and surrounding soil.

2. Determination of watts lost as related to the temperature curve under various conditions.

3. Best arrangement of ducts to reduce heating to a minimum.

4. Determination of a reliable method of rating cables.

Papers on Transmission and Distribution

There has been considerable discussion during the past year of the desirability of erecting high-voltage tie lines to connect existing or proposed, large power developments.

A paper presented at the Pacific Coast Convention in Los Angeles, September, 18th, 1919, by Messrs. R. W. Sorensen, H. H. Cox and G. E. Armstrong, deals with the high-tension tie line in so far as the state of California is concerned.

The authors summarize the power resources of the state, estimate the probable 1926 demand, and discuss the advantages of an all state tie line. The paper points out that the fundamental problems in 220,000 volt transmission are well understood, and that as the need of such a line is imperative, arrangements should be made without delay for the working out of details, and the construction of the line.

The super-power generation and transmission problem for industries and railroads on the North Atlantic Seaboard has been very thoroughly covered in a paper in the JOURNAL for March, 1920, by Mr. W. S. Murray.

The author's plan, which has the endorsement of the important engineering societies, provides a means whereby the present estimated machine capacity of 17,000,000 horse power, divided 10,000,000 for industrial and 7,000,000 for railroad purposes, in the region between Boston and Washington, can be lifted from a present load factor of 15 per cent to a load factor of 50 per cent or more.

By utilizing the more economical generating apparatus at such a high load factor, it is expected that present fuel consumption can be cut in half and that

the railroads can be relieved of carrying a considerable amount of the coal which is annually transported to the seaboard.

In conjunction with Mr. Murray's paper there also appeared in the March, 1920 JOURNAL, a symposium giving the views of a number of eminent engineers on the subject of super-power generation and transmission.

In the April, 1920 JOURNAL, Mr. H. H. Plumb has contributed an extremely interesting paper on a rational method of determining the economic voltage for a long transmission line. The paper presents a rapid solution for the size of copper conductor based on Kelvin's law, and with this as a foundation, develops the solution of the economic voltage for copper, copper-clad steel, aluminum and other conductor materials.

Mr. W. A. Del Mar in the January, 1920 issue of the JOURNAL, has worked out a method by which different insulating materials may be compared even when the tests are made at different voltages, and on cables of different sizes. This method consists in expressing the specific quality of the insulation, in terms of a quantity which may be termed the coefficient of dielectric loss, and which is the product of the power factor and the specific inductive capacity.

TENDENCIES IN HIGH-VOLTAGE TRANSMISSION

The probable magnitude of the power requirements of the near future, together with a quickened appreciation of need for maximum economy in its production has led to widespread and serious consideration of projects for bulk transmission of power to load centers from distant energy sources. It is of interest to note that similar conditions exist and similar projects are being considered in many foreign countries. The large amounts of power and the long distances involved in such projects are beyond the economic range of transmission voltages thus far in use. In consequence there has been, during the past year, considerable study and discussion of the feasibility, design, cost and characteristics of transmission at a materially high voltage.

The study and discussion have centered largely around 220 kilovolts which has appeared to represent a sufficient increase in transmission capacity to meet the requirements of projects thus far under discussion, and at the same time involve no such large step beyond present practise as to introduce problems not susceptible of present commercial solution.

Development of trunk transmission at such a voltage as 220 kv. would involve new problems arising from the high voltage, the large amounts of power involved, and the high service standards which the importance of the transmission would demand. The various studies which have been made indicate that these problems differ in degree, but not in character, from those satisfactorily handled in present practise. The production of equipment for such a voltage has been the subject of thorough study and investigation by the manufacturers, and definite assurance is given that equipment entirely adequate for the service can be supplied. For transformers in suitably large units for voltages of the order of 220 kv. it is stated that no radical departures are involved in either design or construction. As regards oil circuit breakers, where the problem is one of high capacity rather than of high voltage, it is claimed that satisfactory designs have been worked out. In general, for extr ahigh voltage installations the conclusions from various studies have been that design policy should tend to extreme simplicity of layout and staunchness of equipment. One feature of this policy would probably be omission of arresters or similar protective equipment. While present type of arresters could presumably be adapted for such a voltage, it appears to the opinion of those who have thus far studied the problem that they would be neither needed nor efficient. The idea appears to be becoming quite general among operating engineers that arresters of the usual type, with a series gap, afford little protection against dangerous low-voltage high-frequency surges, while the need for protection against excess potentials becomes progressively less for the higher operating voltages. Both theoretically and in the light of such experience as is available, circuits operating near the corona limit will tend to be self protecting against excess potentials as a result of corona dissipation, while atmospheric lightning disturbances in general appear to have relatively less destructive effects upon lines and apparatus for the very high voltages.

It appears probable that the one problem of 220-kv. transmission to which present practise cannot satisfactorily be extended without considerable modification is that of line insulators. While it is believed that present commercial types of suspension disk insulators could be made to give acceptable service, they are not regarded as likely to prove wholly satisfactory. Even if it could be assumed that the deterioration which has constituted such a serious defect with the earlier disks has in recent types been adequately overcome, it would still appear that both the electrical and mechanical characteristics of these insulators are not well adapted to the conditions of extra high voltage service. With long strings there is an excessive concentration of potential on the end disks and very little would be added to the total flashover of the string by increasing the number of disks. For 220 kv. this condition appears to be so pronounced that probably some remedy would have to be devised. It has been suggested that grading by using several types of disks with different electrostatic capacities would effect an improvement in the potential distribution over the string, although maintenance would be somewhat complicated, while another suggestion is for the installation of suitably shaped electrostatic shields at the ends of the strings. A difficulty con-

sidered even more serious is that mechanically these disks are not strong enough, in a single string, to support with adequate margins of safety the extreme loads which have been assumed as called for by 220 kv. service, due to the large size of conductor, the long spans probably demanded by considerations of economy and the heavy design loadings which the high service standards would dictate. The complication attending the use of two-string or three-string assemblies for suspension units is considered highly undesirable. In view of these limitations of the present commercial type of high-voltage insulator, the need for an improved or radically different design for higher voltages has been strongly emphasized. Some of the insulator manufacturers appear to be making extensive investigations and experiments in this field.

The long lines and high load capacities per circuit, conditions which call for extra high voltage service, have led to the recommendation that voltage be controlled mainly at the receiving end, either by synchronous condenser installations operated as an integral part of the circuit or, where practicable, by the use of excess generator capacity in the receiving system. For a given amount of power to be transmitted, ample condenser capacity, by improving voltage regulation, would reduce the number of circuits otherwise needed and by reducing the values of line current would permit of economical use of smaller conductors.

For 220 kv. transmission the expensive character of substation apparatus and the greater insurance of immunity from operating troubles which is afforded by simplicity of system would both favor keeping to a minimum the number of connections. It may be presumed that the tendency in developing such a system will be to use the high voltage for trunk transmission only, existing lower voltage transmission systems or extensions thereof being employed in general to reach customers and minor or secondary load centers.

The practise of interconnecting power supply systems in adjacent territories, which, during the war, gained new impetus as a result of the need for obtaining the maximum effective output from existing generating capacity, has been further extended, and numerous plans are in progress or under discussion for interconnections of considerable magnitude. The great interconnected system in the Southeastern states has been extended and the interconnections reinforced.

This movement toward interconnection is hastening the tendency, already evident, toward uniformity and simplicity in transmission standards and practises. Standardization of voltages in multiples of 11 kv. is well established, accepted steps being 22 kv., 33 kv., 44 kv., 66 kv., 88 kv., 110 kv., 132 kv., and 154 kv., with 220 kv. projected as the next step. Certain earlier standard steps, such as 60 kv. and 100 kv., are no longer used except in connection with existing systems. The advantage of keeping these standard voltage steps to a minimum are so great, even more from the point of view of future interconnection than of economy in manufacture, that certain of the steps in the above list may fall into disuse. Eighty-eight kv. for instance, does not seem likely to be continued as a standard, while possibly either 33 kv. or 44 kv. and either 132 kv. or 154 kv., may tend to drop out. Sixty cycles, likewise, is becoming firmly established as the standard frequency for the United States, and its virtually exclusive use for general power supply can be predicted for the near future. The practise of using a grounded neutral connection for the higher voltages is considered to have clearly demonstrated its superiority and is rapidly supplanting the isolated delta connection, while for larger systems at least the preference for the grounded neutral connection is evident also in case of the lower voltages.

In general, it is coming to be clearly recognized that interconnection of power supply systems is not to be merely an occasional expedient but the normal condition, and that it will tend to become more and more extensive, adjacent systems being connected into groups, and these groups being joined by trunk transmission lines into systems covering a number of states, probably leading eventually to an interconnected system of nation-wide proportions. With this tendency toward widespread interconnection so unmistakeable, an important obligation rests upon the engineering profession to so plan present work as to enable it to fit into such development with a minimum of waste, particularly in such matters as standardization of voltages and frequencies in adjacent territories. The establishment of a comprehensive power supply system, district or regional, will mean much to the future of the electrical power industry and to the industrial future of the country, in which the question of power supply is clearly destined to become one of the determining factors.

Tendencies in Underground Cable Practise

The lack of accurate information on certain elements influencing the operation of underground cables, has in the past caused this branch of the transmission and distribution to be neglected to some extent, and some of the operating companies have been put to a great deal of trouble and expense on this account. At present, however, there is a growing interest in this subject which has already resulted in a marked improvement in the manufacture of cables, so that the carrying capacity of cables manufactured today is materially greater than that of cables manufactured a few years ago.

The principal improvement is the reduction of dielectric loss at relatively high temperature. This has been accomplished principally as the result of a thorough study of the properties of impregnating compounds. It is now possible to manufacture cable the rating of which will be decreased only a few per cent under temperature as high as 100 deg. cent.

These refinements in manufacture make the three phase underground cable fairly satisfactory for voltages up to 25,000, and for loads per circuit up to 10,000 kw., but if these limits are to be exceeded it will probably be necessary to go to single conductor construction.

During the past year there have been a great many serious burnouts on underground systems where trouble was communicated from one cable to another until sometimes a whole duct line was involved, and at present there is a great deal of attention being given to methods for the prevention of the spreading of such troubles.

Results have been improved by changes in the design of duct lines, such as the wider separation of ducts especially where they enter the manhole. This wider separation tends to prevent the communication of trouble from one cable to another which is very dangerous where there are a great number of important cables in one line. For the same reason it is now the prevailing practise to use some form of conduit construction that gives an individual wall of concrete around each duct, as concrete is a very good arc-resisting material.

Protection of cables from fire in manholes by cement covering is still the prevailing practise. Methods of applying the cement varies to some extent, but the results are uniformly satisfactory.

There is also a recognized advantage in installing separate duct lines for cables operating at widely different voltages in order to avoid the possibility of limiting the load on some of the cables on account of the temperature limits of cables working at another voltage. This temperature influence is very important and should always be considered when there is a possibility of extreme limitations being placed on some cables by the influence of others.

As regards sizes and types of underground cable, manufacturers report a steadily growing demand for cables of 350,000 to 500,000 cir. mils. There is also a tendency on the part of customers to specify sector type cable on account of the smaller overall diameter for a given copper cross section.

The installation of these large size cables makes it more difficult to bend and train the cable in manholes and in some cases requires a modification in the design of manholes to avoid sharp bends.

The rectangular manhole with duct openings in the center of, and flush with one wall, compels the bending of the cable at too short a radius. Oval or rectangular manholes can be used, but as these shapes are not entirely satisfactory, it has been proposed that the rectangular manhole be set at 45 degrees with the center line of the conduit, and the duct entrance be recessed so as to permit of training through the manhole with long radius bends.

The Hochstadter type of cable in which the individual conductors are covered with a thin metal foil, and the assembled conductors sheathed without belt insulation, is now being supplied commercially.

Users of split conductor cable report satisfactory operating results and state that the advantages of the selective protection obtained by the use of this type of cable more than offset the disadvantage of the smaller current-carrying capacity for a given duct size.

E. B. Meyer, *Chairman.*

ANNUAL REPORT OF THE IRON AND STEEL INDUSTRY COMMITTEE

To the Board of Directors,

DURING the Convention held at Lake Placid in June, 1919, Dr. C. P. Steinmetz in discussing the work of the technical committees of the Institute expressed the belief that the annual reports of such committees should be planned to provide for the use of the entire membership of the Institute, a comprehensive record of the present status and recent progress of electrical engineering in the particular industry or branch of the art to which each committee had been organized to apply itself.

Accordingly, Mr. Wilfred Sykes, the Chairman of the Board's Committee on Technical Activities, suggested to the various 1920 Technical Committees that their reports "should cover notable installations or developments during the year and in view of the fact that, in the past, little has been done in this respect, that the reports for 1920 might be a review of the state of the art up to date."

Guided by these suggestions it has been the aim of the Iron & Steel Industry Committee, to at least prepare as a foundation, the present status of electrical application to the iron and steel industry, upon which subsequent committees might base annual reports showing recent progress. The field is an extremely broad one dealing as it must, with practically every process in the transformation of the raw material inos the many forms of finished product. Electricity it utilized in the handling of the ore and provides the means of handling the finished products as well as the final heat treatment of the more highly developed products. From the mechanical point of view, it has been stated that from the ore to the finished product the hand of man has no occasion to touch the materials and it can be stated further that throughout this same transformation, practically no step is taken in which electricity is not playing an increasingly important part.

While the iron and steel industry in America, dates back into the country's earliest history, electricity only comparatively recently began to play its important part, to be more exact, about 1891. At present the total generating capacity required by the industry is approximately one million kilowatts and each new

development in the art of steel making opens up new fields for electrical application so that in many important respects, the making of steel is becoming an electrical industry.

Supplement A has been prepared to indicate the major applications of heat and power entering into the making of iron and steel products from the raw materials, and to show the extent to which electrical heat and power have been or may be applied. As to the auxiliary applications of power in the handling, manipulating, and finishing of the materials and products, electricity is almost universally used as supplementary data will show.

It was decided to consider the mining of the raw materials as outside the scope of the Iron & Steel Industry Committee and it has dealt only with the material after arrival at the blast furnace. Reference again to Supplement A will indicate the processes to which the Committee has applied itself. Furthermore, it has not been intended to prepare a handbook for electrical engineers engaged in the iron and steel industry, but rather provide a source of general information for the large proportion of the Institute membership engaged in the many other lines of electrical engineering.

Using Supplement A as a basis, memorandums have been or are being prepared along the following general lines, believing that brief considerations of each subject separately, could be used to better advantage and more readily added to than to attempt a consecutive description.

Blast Furnace Group

Memorandum A 1—The status of iron ore smelting in the electric furnace.

Memorandum A 2—Synthetic electric furnace pig iron.

" A 3—The electrical precipitation of dust of blast furnace gases.

Electric Melting Furnace Group

*Memorandum B 1—Statistical data—The growth of the application of electric furnaces.

* " B 2—Types and electrical characteristics.

Electric Heat Treatment Furnace Group

Memorandum C 1—Electrical heated soaking pits.

" C 2—Carbon resistor type furnaces.

" C 3—Typical heat treating plants (Carbon resistor).

* " C 4—Metallic resistor type furnaces.

Rolling Mill Group

*Memorandum D 1—Statistical data.

* " D 2—Types of Drives—Non Reversing — Adjustable — Speed — Reversing.

Miscellaneous Group

*Memorandum E 1—The electric hydraulic system as proposed for large forge presses.

The Committee has prepared and sent to all the principal Iron and Steel Companies, the following Questionnaire and the results will be tabulated as a general indication of the extent and characteristics of both electric power supply and application. This data will appear in the form of Supplement B at an early date.

ELECTRICAL STATISTICS

Name and location of plant..

POWER SUPPLY (period January to December, 1919, inclusive)

Purchased from central stations......................... kw-hours

Generated by own steam units from coal-fired boilers....... kw- "

" " " " " from gas or waste heat boilers kw- "
(including exhaust pressure turbines)

" " " gas engines using waste gases........... kw- "

MOTOR EQUIPMENT a-c....phase...cycle...volts d-c....volts

Number of motors............. ....

Total horse power............. ....

GENERATING CAPACITY a-c.....volts. d-c.......volts.

Average kw. capacity in use—kw..... kw.......
Average load factor......... %.... %......
{ Do not include sub-station d-c. apparatus }

*In preparation for issue at an early date.

Meetings and Papers

No attempt has been made to secure papers or arrange Institute meetings for the consideration of Iron & Steel Industry subjects, owing to the extensive interlocking of the memberships of the A. I. E. E. and the Association of Iron & Steel Electrical Engineers which holds monthly meetings of high grade in Pittsburgh, Cleveland, Chicago, Birmingham and Philadelphia. In some cases joint meetings between the local sections of these organizations have been successfully held and an extension of this practise is recommended. The nature of the papers presented at the A. I. & S. E. E. meetings is made clear by the list supplementing this report (Supplement C) and it is recommended that closer relations be established between the two organizations through the publication, in the JOURNAL of the A. I. E. E., of notices before and after the A. I. & S. E. E. meetings, together with other items of mutual interest.

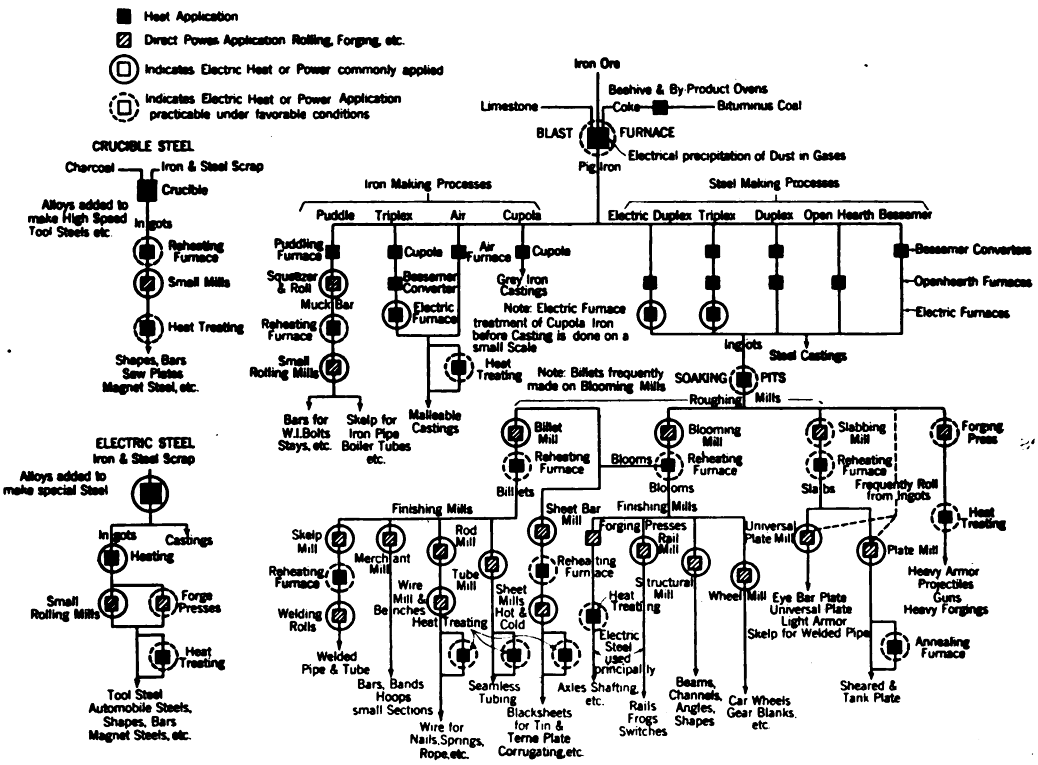
It is further recommended that the Board of Directors consider the scope of the work of the Association of Iron and Steel Electrical Engineers and with the appointment of the iron and steel industry committee for the coming year, formulate a definite policy as to the nature of the Committee's activities in order to avoid duplication of effort on the part of the two organizations, the memberships of which are closely interlocked.

The Board of Directors of the A. I. E. E. has authorized this Committee to discuss with the Board of the A. I. & S. E. E. the question of co-operation in the matter of Standardization Rules and it is regretted that no opportunity for such conference has presented itself. Such action is strongly recommended at an early date.

Many valuable papers relative to electric furnaces in the Iron & Steel making processes are presented in the meetings of the American Electrochemical Society and are recommended for notice and possibly publication in the A. I. E. E. JOURNAL.

The Committee wishes to acknowledge with thanks, the hearty co-operation it has received from the individuals and Companies appealed to in the gathering of the data presented herewith.

frequencies as high as 60 cycles, but 25 cycles is preferable in the large units, such as used in Sweden. The load factor can be made high and the units vary from 2000 to 7000 kw. in capacity. The furnace voltage is low, being below 100 volts, and voltage regulation is accomplished by means of taps in the high tension side which limits the use of very high transmission voltages without intermediate stepdown transformers.



ELECTRICITY IN THE MAKING OF IRON AND STEEL PRODUCTS

NOTE—Practically all auxiliary applications of power for the transportation, manipulation hoisting, pouring, shearing, finishing, magnetic lifting, etc. of the steel and iron materials, raw materials and machinery or tools used, are electrical.

MEMORANDUM A 1

THE STATUS OF IRON ORE SMELTING IN THE ELECTRIC FURNACE

The electric method of smelting of iron ore is in no sense competitive from a commercial point of view with the blast furnace, as commonly used in the manufacture of pig iron, in America.

Pig iron of high grade can be made in the electric furnace, and is so made in considerable quantities, but only at localities that combine the conditions of having ore and charcoal accessible to dependable low cost electrical energy, not exceeding twelve to fifteen dollars per horse power year. The industry has therefore, been confined largely to Norway, Sweden, Italy, with smaller installation in Japan, Switzerland, California and Canada. British Columbia is being considered as having the necessary requirements.

Three-phase furnaces are commonly used and power factors of from 65 to 95 per cent are possible with

The furnaces used in Sweden where the greatest amount of electric pig iron is produced (approximately 70,000 tons in 1918) consist of a furnace shaft quite similar to a small blast furnace independently supported above a relatively shallow crucible of larger diameter which is covered by a circular arch through which the carbon electrodes project into the charge which is fed to the top of the furnace as in a blast furnace.

MEMORANDUM A 2

SYNTHETIC ELECTRIC FURNACE PIG IRON

Conditions of shortage of pig iron and the unusual availability of steel turnings incident to the war period, developed the manufacture of synthetic pig iron in electric furnaces by re-carburizing fusion of steel turning or scrap. This process was used principally in Canada and France, the latter country having made at Levet, Nanterre and Limoges over 150,000 tons during the war period. The future of this industry depends upon cheap water power,

availability of materials and the relative cost of coal.

Typical Furnaces in Canada. A small 250-kw., single-phase furnace at Orillia, Ontario, produced six to seven tons of low phosphorus pig iron per twenty-four hours. A six-ton, three-phase furnace at St. Catherines, Ontario, with 1200-kw. transformers produced approximately 20 tons per day, with a 700-kw. input and with full 1200-kw. input—35 tons per day. For each hundred weight of turnings charged, there was added 5 per cent in the form of carbon and silicon and the yield was approximately 95 lb. of pig iron. The furnaces were of the enclosed type as usual to the making of steel and the current was of standard frequency. The load factor and power factor can be made high.

The French Furnaces. Open type furnaces of greater capacity, are used and are principally of single-phase construction with one moveable electrode and the other imbedded from below in the hearth. Standard frequencies with high load factor and power factor prevail. A 2500-kw. furnace produces 80 to 100 tons per day with a power consumption of 675 kw-hr. per ton. Complete foundries for the casting of shells were in some cases located adjacent to the pig iron furnace and by a further treatment in single-phase electric mixing furnaces of closed type, with an expenditure of approximately 50 to 100 kw-hr. per ton, the metal was made to meet the specifications for such castings (carbon 2.90, silicon 1.75, manganese 0.50, sulphur-trace, phosphorus 0.05).

These single-phase mixer furnaces are operated in groups of three and have one adjustable electrode above with the other electrode imbedded in the hearth from below.

MEMORANDUM A 3

The Electrical Precipitation of Dust of Blast Furnace Gases

The Cottrell system of electrical precipitation has been applied in two instances to the cleaning of blast furnaces gas. The advantages are such that such equipment is likely to become common among the blast furnaces.

In applying this system the gas piping from the blast furnace is arranged so that the gas is conducted through a group of vertical pipes from bottom to top and the high-tension electrode in the form of chains or wires held taut by weights, are supported in the center of the pipes from insulators at the top. The dust and fume particles are repelled by the charged electrode and are deposited on the sides of the pipes from which it is jarred by vibration of the pipes at suitable intervals (once each hour or more). This jarring can be accomplished automatically by relays adjusted to voltage drops and amperage increases which occur when the accumulation of dust becomes excessive. During the shaking down of the dust the precipitating apparatus is shut down for the necessary two or three minutes required.

A typical installation, put into service during 1919, takes three-phase, 60-cycle, 220-volt current from the power system, two 25-kv-a. transformers in open delta being ample for the entire power requirement which is 15 to 20 kv-a. to clean 45,000 to 50,000 cubic feet of gas per minute. The 220-volt current is applied to a small synchronous motor operating at 1800 rev. per min. and driving a mechanical rectifier, and is also fed through transformers which step the voltage up to 35,000 to 50,000 volts, adjustable by taps. The rectifier converts this high-tension current to the undirectional current required by the precipitating electrode. The equipment can be made to suit any standard frequency.

A second installation has been made more recently in connection with a blast furnace and is of about one half the capacity of the first equipment.

MEMORANDUM C 2

Carbon Resistor Type Furnace for Steel Treating

Furnaces of this type are usually rectangular in shape with doors at each end for the receipt and delivery of the materials to be treated. Parallel with the length of the furnace, one on each side, are located two resistor troughs. The resistance elements composed of broken carbon are thrown loosely into these carborundum fires and troughs which are supported on brick pillars along the side wall and protected by being recessed back from the space into which the steel materials are introduced. The heat from the resistance element is radiated to the walls and top of the furnace which is lined with refractory materials which become heated and in turn heat the charge. Carbon or graphite electrodes at each end of the troughs provide the means of introducing the current and the control of the current, hence the heat is effected by varying the voltage impressed at the electrodes, this variation being obtained by means of numerous taps on the secondaries of the special transformers.

The materials to be treated are in some cases put into the furnace on cars for a period treatment and in other cases the operation is continuous, the materials being slowly pushed or conveyed through the furnace.

Advantage is invariably taken of the possibility of making these furnaces automatic, both as regards the cycle of temperature treatment and the charging and discharging.

The following list of furnaces, together with the dates of installation, will indicate the development and application in steel treating:

Plant	Date	Application	No.	Electrical capacity each	Tons of steel heated per 24 hours
No. 1	1915	Annealing castings	1	150 kw.	12
2	1916	Annealing castings	1	300 kw.	24
3	1916	Treating draw-bar knuckles	2	1–600 kw. 1–300 kw. Tandem operation	144 total
4	1916	Annealing steel castings	1	600 kw.	12
5	1917	Treating small steel parts for aeroplanes and tractors	1	150 kw.	24
6	1917	Treating auto gears	1	40 kw.	4
7	1918	Duplicate of plant	3		
8	1918	Duplicate of plant	5		
9	1918	Annealing R. R. axles	1	150 kw.	12
10	1918	Treating cast steel anchor chain	2	1–600 kw. 1–300 kw. Tandem operation	150 total
11	1918	Treating Crank shafts for liberty motors		1–600 1–300 Tandem operation	144 total
12	1918	Annealing steel	1	600 kw.	75
13	1919	Roller bearing and ball race treatment	1	150 kw.	12
14	1919	Annealing steel sheets	1	600 kw.	150
15	1919	(2) Duplicate of plant	10		
16	1920	Treating bolts and nuts	1	40 kw.	4
17	1920	Roller hardening	1	75 kw.	5

MEMORANDUM C 3

Typical Heat Treating Plants

(Carbon Resistor Type)

Plant A. Automatic furnace handling roller bearing and ball races.

Materials to be treated are placed in metal baskets holding approximately 125 lb. each and fed into one end of rectangular carbon resistor type of furnace maintained at approximately 1525 deg. fahr. by an input of 150 kw. A clock contactor regulates, over a variable range, the rate of flow of material through the furnace and ordinarily 1000 to 1200 pounds of material is handled per hour.

The discharge of the heated material is into a drawing or quenching tank, the oil of which is maintained at a temperature of approximately 350 deg. fahr. by means of immersed nichrome resistors requiring about 40 kw.

The temperature control of the furnace and drawing tank is by pyrometers and the adjustable clock contactor devices make the operation entirely automatic as to the temperature, the time in the furnace and the time in the tank. Motor-driven conveyers, door operating mechanisms and oil pumps are all under the control of the time and temperature measuring devices.

Plant B. Annealing furnace for treating low carbon cold rolled strip.

The annealing furnace is approximately 225 ft. long and 22 ft. wide with the heated chamber in the middle. Two parallel tracks pass through the furnace and heated chamber and cars of steel strip each holding about 20 tons of material are fed on to tracks from opposite ends, the purpose being to absorb in the cold carload on one track the heat from the heated carloads on the other track on the way to the discharge point.

The temperature attained in the electrically heated chamber is approximately 1200 deg. fahr. A movement of the cars takes place every six hours, discharging one twenty-ton car of material at each end or approximately 150 tons of annealed material per 24 hours with an electrical input of approximately 120 kw-hr. per ton.

Plant C. Annealing furnace for treating alloy steel.

Arrangement is similar to Plant B except furnace is shorter and the nature of the steel requiring a 40 hour treatment at about 1400 deg. fahr. The ten cars in the furnace at one time each hold 30 tons of steel or a total of 500 tons, 120 tons of which is in the middle electrically heated chamber. The delivery is approximately 72 tons per day with an electrical input of approximately 250 kw-hr. per ton of metal annealed.

SUPPLEMENT C

Representative Papers Recently Read Before the Association of Iron & Steel Electrical Engineers Main and Section Meetings.

Organization of Electrical Department in the Iron & Steel Industry
- Inspection and Operation.
- Educational Training for Employees.
- Electrical Repair Shop.
- Storeroom and Spare Parts.

Records and Tests.
A-C. *vs.* D-C. Motors for Rolling Mill Table Drives.
Recent Improvements in Industrial Control.
Present Status of Electric Furnaces in the Steel Industry
Electric Heat Treatment.
Overload Protection for Motors.
Overload Protection on Cranes.
General Specifications for A-C. Motors for Main Roll Drive.
Present Status of Arc Welding in the Iron & Steel Industry.
Safety Rules for Government of Employees Working on Electrical Equipment.
Babbitt and Babbitting.
Grounded Neutral.
Current-Limit Reactance.
Welding, Electric *vs.* Gas.
Electric Rolling Mill Drives.
Steel Plant Power Generation from Waste Heat and Coal.
Electrical Equipment of the Largest Plate Mill in the World.
Electrical Installations at Trumbull Steel Co.
Steam *vs.* Electric Driven Mills.
Electrical Features of a Modern Steel Plant.
Steel Mill Electrical Repair Shop Practise.
Influence of Gear Ratio on Speed of Operation, Motor Heating and Contactor Wear in Auxiliary Steel Mill Drives.
Automatic Electrolytic Oxy-Hydrogen Plant.
Heating of Underground Cables.

ANNUAL REPORT OF THE INDUSTRIAL AND DOMESTIC POWER COMMITTEE

To the Board of Directors,

THE Industrial and Domestic Power Committee has continued its earlier plan of work without change or modification. We are convinced that it is sound. We know the results now appearing will justify the study. We strongly urge its continuance.

Eleven sub-committees are analyzing electrical power applications in eleven different branches of industrial activity. The analysis consist of a study of the various processes involved, the movements in the processes and the electrical application to the movements. No standardization studies are considered. This is a province of other committees. The work is entirely ethical. In no way is our work overlapping studies by other Institute committees, or by committees external to the Institute.

A similar study of the electrical power applications in the use of prominent industrial tools is being conducted.

The work is being reported by monographs. Each monograph comprises a section of sub-committee study, complete in itself and yet forming a part of the whole. Each sub-committee is planning its own work to its own ideas, but all in conformity to the general plan. In the final execution of the plan, a progression of monographs carefully edited and approved by the Industrial and Domestic Power Committee will reach Headquarters and will be available for presentation to Section or Institute meetings; for publication in the JOURNAL or for sale by Headquarters at a nominal fee. With the interest being generated in the plan, we look confidently for extremely valuable returns; for treatises on industry of practical value. They in no sense can replace the work of the consulting engineer. They should be a guide in the study and planning of industrial applications.

In our work we have been helped by men not of the main committee, but regularly appointed by the President to our several sub-committees. These appointments have been cheerfully accepted, and such results as are being obtained are because of their service, and we may suggest that this plan has brought into active Institute service men whose abilities for such service were not otherwise being reached.

The personnel of the several sub-committees follows:

1. SUB-COMMITTEE ON MOTORS WITH PARTICULAR REFERENCE TO SPEED TORQUE CHARACTERISTICS.

A. M. Dudley, *Chairman.*

R. H. Tillman, A. C. Lanier,
Wilfred Sykes, John C. Parker.

2. SUB-COMMITTEE ON DOMESTIC POWER APPLICATION.

H. Weichsel, *Chairman.*

James Dixon, C. L. Kennedy,
A. F. Welch, L. L. Keilholtz.
Bernard Lester, Edgar D. Doyle.

3. SUB-COMMITTEE ON APPLICATIONS IN PRINTING INDUSTRY.

W. C. Kalb, *Chairman.*

W. E. Date, John D. Nies,
J. C. Lincoln, Carl F. Scott.

4. SUB-COMMITTEE ON APPLICATIONS TO CRANES AND HOISTS.

R. H. McLain, *Chairman.*

H. W. Eastwood, E. Friedlaender,
James A. Shepard.

5. SUB-COMMITTEE ON APPLICATIONS TO MACHINE TOOLS.

H. D. James, *Chairman.*

T. E. Barnum, W. C. Yates,
W. T. Snyder, R. H. Goodwillie.

6. SUB-COMMITTEE ON APPLICATIONS TO PASSENGER AND FREIGHT ELEVATORS.

R. H. Goodwillie, *Chairman.*

H. D. James, H. P. Reed,
David L. Lindquist, Charles H. Roth.

7. SUB-COMMITTEE ON APPLICATION IN TEXTILE INDUSTRY.

H. W. Cope, *Chairman.*

C. T. Guildford, S. B. Paine,
J. C. Ramsay, D. H. Sadler.

8. SUB-COMMITTEE ON APPLICATIONS IN CEMENT INDUSTRY.

R. B. Williamson, *Chairman.*

H. Weichsel, C. A. Kelsey,
J. F. Siegfried, Arthur Simon,
S. A. Staege, M. R. Woodward.

9. SUB-COMMITTEE ON APPLICATION IN WOODWORKING INDUSTRY.

L. E. Underwood, *Chairman*

Truman Hibbard, Robert L. Smith
S. A. Staege.

10. SUB-COMMITTEE ON APPLICATION OF ELECTRIC ENERGY IN INDUSTRIAL HEATING.

E. V. Buchanan, *Chairman.*

T. E. Penard, H. O. Swoboda,
W. S. Scott, H. A. Winne.

11. SUB-COMMITTEE ON APPLICATIONS IN RUBBER INDUSTRY.

W. E. Date, *Chairman.*

M. Berthold, A. C. Bunker,
B. T. Mottinger, C. A. Rice,
H. F. Schippel.

Most of the sub-committees have made reports of their activities for the term. It is impossible to give these complete in this report without making it unwieldy. It is impractical to condense them. They should have individual consideration, and their reading amplifies this picture of our work. For this reason they are forwarded herewith for the information and consideration of the Board of Directors. The sub-committees in the main have worked hard and conscientiously to develop the plan, the main committee acting as a clearing house, and in an advisory capacity. All sub-committee chairmen are members of the parent committee. But the burden of the work has fallen to the sub-committees, and their work merits every appreciation.

The outstanding feature in electrical industrial development during the present term has been magnitude of production. Demand has continued greater than supply taxing combined production to the greatest limit. Probably the development and increase in use of fractional horse power motors for domestic and small industrial use has been the greatest

contributing factor in this total. In this fractional field, quantity of production especially is to be emphasized. In general, quantity demand has been the real problem, the design and application of new productions being forced to second place.

In larger horse power fields, the increasing use of the synchronous motor is to be noted. As a corrective of the power factor of industrial loads it continues not only desirable but a growing necessity to meet a continual problem. In this connection, the use of the static condenser has continued as a power factor corrective.

The use of the direct-current motor in its several types continues accurately as does the use of the induction motor. In general there is continued progress in the standards of application of the several types of motors and in the recognition of these standards and away from misapplication, and great credit must be accorded to the discerning intelligence of the engineers connected both with the production and use of motors that has cooperatively tended to bring this about.

The Industrial and Domestic Power Committee particularly appreciates the advice of your committee on technical activities, together with the help constantly accorded from our Secretary's office at Headquarters. As a committee, we have tried to recognize fully the trust imposed and bespeak for our successors your full cooperation in the work we are undertaking.

A. G. Pierce, *Chairman.*

ANNUAL REPORT OF THE MARINE COMMITTEE

To the Board of Directors,

It will no doubt be recalled the inception of the Marine Committee was in 1913. Little actual work was accomplished by this Committee until last year, when the compilation of a set of rules for electrical installation on shipboard was started, together with dissemination of knowledge relative to that subject to the electrical engineers of the newly created ship yards.

The enormity of the work, that of preparing the Marine Rules started, was the more fully appreciated as the work progressed, and while the work of last year's committee was very commendable, the volume of the work completed was performed by this year's committee. The number of members constituting the committee this year was greatly reduced to facilitate the work and curtail expenses as much as possible.

Eight meetings of the committee were held. The first meeting was given over to the appointment of the various Committees and the outlining of the work of each. The Ship Installation, Marine Propulsion and Historical Committees constituted the main divisions. The first two of these committees were supplemented by sub-Committees to look after the vast amount of detail work involved in the activities of the main committee.

In last year's Annual Report of the Marine Committee it was suggested that the unfinished work of that Committee be continued this year. This unfinished work consisted of the completion of the rules for governing the installation of electrical apparatus on shipboard. The work on these rules that was not completed consisted of the following:

Revision of Rules prepared last year.
Control Equipments.
Alternating Current Apparatus Control.
Radio Installations.
Running Lights, etc.
Fire Alarm Systems.
(not completed by sub-Committees.)
Tabulation of Generating Sets.
Storage Battery Installation.
Gyro-Compass Installation.
Gyro Stabilizing Installation.
Tabulation of Wires and Conductors.
Appliances in vicinity of Compass.
Inspection Report to Classification Societies.

The Rules for Electrical Installations, as stated above, have now been completed and are in the hands of the secretary to be passed on by the Board of Directors. These Rules will be published in pamphlet form and it is the intention that they be sold at a nominal figure.

Too much credit cannot be given to the various Members of the Ship Installation Committee and the Chairman, Mr. G. A. Pierce, in particular for the work accomplished, as we believe these rules to be the most complete and comprehensive ever formulated by any society, covering as they do practically every phase of the electrical field as applied to ship work and extending the field of the Institute to practical installations. This being an innovation on the part of the Institute, the attitude of the ship owners, builders and classification societies relative to their adoption is eagerly awaited. Several new features are also introduced, which will probably extend the field of this work to a marked degree.

The rules as now completed have been referred to the various classification societies and the emergency Fleet Corporation, all of which were given them opportunity to comment. This method of action has gone far to put in composite form the work as viewed from the different angles. When published, copies of the rules are to be forwarded to the Institute of Electrical Engineers of England, France and Italy.

As the work of the Ship Installation Sub-committee neared completion, it was found that, due to the magnitude of this work, it would be necessary to have someone care for the preparation of it, in order that it could be put in final form for publication. It was

therefore decided to appoint an Editing Committee, whose duty it would be to correlate the vast amount of information contained in these rules. The work of this committee was no easy task and we therefore take this opportunity of complimenting it on its labors in connection with this work.

The Marine Propulsion Committee has prepared its historical and data work and it is suggested that this be put in form to be published in the JOURNAL of the Institute, as a means of drawing out discussion and additional data as regards this subject. It was decided to await experience on electrically propelled ships, soon to be put in service, rather than introduce data based on theory only. It is suggested that this feature be given careful thought and consideration during the coming year, as many new ideas will probably result from the experience gained by that time.

Historical Committee

The Historical Sub-committee has prepared a Historical Review of the Use of Electricity on Shipboard. This review accompanies and forms a part of this report. A more complete account will be prepared for publication in the JOURNAL of the Institute. This is considered a very important work, as the evidences of the use of electricity in the marine field are only fragmentary and should be placed in a form of record, as a matter of history. When this is accomplished, it will then be a very simple matter to add, from time to time, the outstanding events in their chronological order. This historical feature is one that should not be lost sight of in the work of future committees.

In line with the requirements of the rules as now completed, governing the installation of electrical apparatus on merchant ships, it is suggested that next year's committee take up the matter of approval of various fixtures, fittings, etc., with the end in view of having these meet the requirements of the new rules. It is believed that the preparation of General Construction Specifications, covering various appliances should be performed by the Marine Committee.

One of the ideas brought forth during the year, was the consideration of terminal facilities at marine piers. This is more or less a new activity, as very little has been done thus far to facilitate the handling of cargoes at these terminals. The field is large and is therefore due a considerable amount of thought.

In conclusion, I feel that particular comment should be given to large attendance of the members of this committee at the regular meetings and the splendid spirit of co-operation existing between these various members. It is only in such harmony that the greater results, for which we all hope, are to be attained.

ARTHUR PARKER, *Chairman.*

HISTORICAL REVIEW OF THE USE OF ELECTRICITY ON SHIPBOARD

The marine field has probably been one of the most backward in the adoption and development of electrical apparatus which in the main, we believe has been due to the traditional conservatism of the seafaring man. While electricity was used to a very limited extent as far back as 1882 for interior communication, watertight bells, buzzers, annunciators, etc., having been installed by the Chas. Cory & Son Co. on the *Santa Rosa* about this time, and in the Navy electrical instruments were installed on the *Trenton* in 1883, apparently one of the first, if not the very first, electric light installations was also made on the *Trenton* about this time, at New York Navy Yard. All early lighting installations were Edison bipolar generators belt driven to an Armington-Sims or other reciprocating type engine. Voltmeters were not used until after the early '80s, and field regulation was not indulged in until about the same time, all of the early installations simply having a pilot light on the generator for gauging the voltage and candle power of the lamps.

Early wiring was installed in wood mouldings, and we believe that Habirshaw wire was considered the standard in the early installations, which was rubber covered with tape outside. Branches were in most cases spliced and the first junction branch boxes were used about 1885-1886. Fuses were used about the same time, usually using an ordinary single fuse placed in the branch circuit on a small insulating base which was inserted in the moulding.

The first marine telephones, we believe, were installed on the U. S. Cruiser *New York* (the first *New York*) about the year 1890. They were single direct circuits, *i. e.*, two telephones used in place of voice tubes. The instruments were of the "Bell" type and installed by Chas. Cory and Sons. The first "loud speaking" marine telephones were installed on the *Korea* and *Siberia* and the U. S. S. *Charlestown*, about 1895.

The first complete central energy (operator's) switchboard telephone systems were installed on the S. S. *Le Grande Duchesse* built at Newport News about the years 1897-1898. Pneumatic electric bells and annunciators were used quite extensively on ships during the period 1878-1890.

While the records are not clear we have every reason to believe that electric bells were installed in the Navy on ships at least ten years previous to the first electric light installation on the *Trenton*.

The most conspicuous example of the use and rapid development of electricity on shipboard has been in the American Navy, which has not only been for years a larger user of electrical machinery than the merchant marine, but also has led the navies of the world in this respect.

Lighting equipments were installed in the Navy on several of the early vessels, beginning with the *Trenton*, and certain power application installed, such as the ammunition hoists on the Cruiser *New York* and the Battleships *Massachusetts*, *Indiana* and *Oregon*, turret turning equipment on the Cruiser *Brooklyn*, and certain

minor auxiliaries such as ammunition hoists on the gun boats *Wilmington* and *Helena.* The extensive use of electrical apparatus for lighting and power purposes was not made however, until the Battleships *Kearsage* and *Kentucky* were constructed in 1898-1900, these vessels having seven 50-kw. engine-driven, 80-volts generating sets, which were operated in series on a 3-wire system to give 80 volts for lighting, and two voltages 80 and 160, for power motors. The major portion of the auxiliaries on these battleships were electrically operated, including the winches, boat cranes, ventilation fans, broadside ammunition hoists and turret auxiliaries. The anchor windlass and steering gear however, were steam driven.

After the *Kearsage* and *Kentucky* some succeeding battleships continued in many of their auxiliaries the use of steam drive, and the *Kearsage* and *Kentucky* are the only instances in the Navy of the use of the 3-wire control.

About 1902 the Navy Department devised an electric steering gear operated on the follow-up system and purchased apparatus of different manufacturers to effect installation on one of the small monitors which had then been recently constructed. The results obtained from this equipment were not satisfactory however. This question remained under discussion for a number of years until about 1909, when a contract was placed for supplying electric steering gear for the Cruiser *Des Moines* with the Cutler-Hammer Mfg. Co. For this purpose the use of an electric motor taking its power direct from the dynamo mains and operated by automatic controller was advocated. The results of this trial equipment were so satisfactory that it eventually resulted in the use of electricity for the steering of all capital vessels in the Navy, the later installations, beginning with the Battleship *New Mexico,* employing the use of the electro hydraulic gear instead of the direct motor drive, and to the exclusion of the steam drive.

Beginning with the Battleships *Nevada* and *Oklahoma,* electrical equipments were provided for the anchor hoist gear, which proved so generally satisfactory that all subsequent capital ships have specified electrical drive for this auxiliary, thus practically completing the application of electricity to all auxiliaries on capital naval vessels.

The use of electricity for lighting and auxiliary power purposes in the Navy having proved so generally successful, the General Electric Co. was granted contract for the installation of electric drive on the Collier *Jupiter* in 1911 which proving satisfactory, a contract was given to the same company for the installation of electric drive on the Battleship *New Mexico,* which continuing the satisfactory results obtained, all battleships and battle cruisers authorized since the *New Mexico* have included the electric drive, and undoubtedly it will remain the means of propelling capital ships of the Navy.

In the submarine branch of the Navy various means of supplying the necessary power for propulsion on early boats when submerged were used, such as hand power, compressed air, and steam. With the development however, of the storage battery, the application of electrical apparatus to the submarine made rapid advancement and made the modern type of submarine possible. In the modern submarine, besides using motors and storage batteries for propulsion purposes, all auxiliary machinery such as hydroplane, steering gear, pumps, windlasses, machine tools, periscope hoists, etc., are electrically operated, electricity also being used for lighting, sound detecting devices and interior communication devices of various kinds. The growth of electricity in the case of submarines may be noted from the fact that the early successful types were equipped only with electric lighting, bell signals and motors for propulsion under 50-h.p., whereas in the most recent electric propulsion, motor power has reached about 3000 h.p. As a matter of historical interest, the first application of the use of propulsion motors for submarines arranged with two armatures on the same shaft was made by the Lake Torpedo Boat Co. on submarines built in Russia for that Government and designed in 1906 and furnished with contactor type of controllers arranged for series parallel operation of the armatures as supplied by the Cutler-Hammer Mfg. Co., this type of motor and system of control being now extensively used in the later submarines of the American Navy.

The American Navy therefore, at the present time, is a user of electricity for practically all purposes for lighting and power and extensively for interior communication work.

While the American Navy has led all other navies of the world in the use of electricity, Europe seems to have led this country in the trial of electrical auxiliaries for use on merchant vessels, and while electricity has been used generally for lighting and some interior communication purposes on merchant vessels for years, it has been employed but to a very limited extent for power purposes until the advent of the oil-engine-driven ship, the most notable instances of this kind being the fleet of vessels constructed by Burmeister and Wain of Copenhagen, the *Christian X* being one of the first vessels so constructed by this company, and its first voyage to this country created marked attention. Since that time it is understood that some 70 or more vessels of this type have been constructed and projected by that Company.

In 1916 and '17 a number of merchant vessels were projected in this country, including tankers and cargo vessels employing electrical auxiliaries, among others being the Tanker *La Brea* with electric operated pumps and the Tanker *Solitaire* just completed by the Texas Co., having oil-engine drive and electrical auxiliaries throughout, including electric heating. Other instances are six tank vessels constructed by the Penn-

sylvania Shipbuilding Co. propelled by geared steam turbines and having electrical auxiliaries.

At the present time there are a number of oil-engine-driven cargo vessels with electric auxiliaries and others with electric drive and electric auxiliaries being projected in this country, and it is believed from this time the field will rapidly broaden until a great many of the merchant vessels will be so propelled and operated.

Extensive progress has been made recently in the merchant field in the use of the electric drive, the first installation on record in this country being two fire boats constructed in 1908 on the Great Lakes. Since these first installations in 1908, a total of 28 electrically propelled vessels have been constructed or projected, all but three of these being built or building in this country. Among these may be mentioned the four tankers constructed by the Pan American Petroleum Transport Co., the trawler *Mariner* equipped at the New London Ship and Engine Bldg. Co.'s works, the passenger ship *Cuba*, the 12 ships projected by the Shipping Board, and the cargo vessel *Wulsty Castle* constructed in England. This growing use of electric drive within the last two or three years would indicate a still further and more rapid adoption.

While the above gives a preliminary and general outline of the history and development of electricity on shipboard, a more complete and detailed historical review of this subject will be compiled during the coming year for submission to, and publication by, the Institute.

H. L. Hibbard

ELECTRIC PROPULSION OF SHIPS (Not Including Naval)

Date	Name of ship	Type of ship	Type of propulsion	Size in tons	S H P	Propeller R P M	A C. or D C.	Voltage	Gen. units	Motor units	Remarks
1910	Jos. Medill	Fireboat	Steam electric	....	500	190	D C	250	2	2	Twin screw
1910	Graeme Stewart	Fireboat	Steam electric	....	500	190	D C	250	2	2	Twin screw
1913	Tynemouth	Cargo	Diesel electric	3400	500	78	A C	500	2	1	Method abandoned as Diesel-engine misfit
1916	Mjolner	Cargo	Steam electric	800	850	90	A C	440	2	2	Geared single screw
1918	Wulsty Castle	Cargo	Steam electric	6400	1500	76	A C	650	2	2	Geared single screw
1918	Panoil	Tanker	Steam electric	1400	620	150–180	A C	440	1	2	Twin screw
1918	Mexoil	Tanker	Steam electric	1400	620	150–180	A C	440	1	2	Twin screw
1918	Fuel Oil	Tanker	Steam electric	1400	620	150–180	A C	440	1	2	Twin screw
1919	Mariner	Trawler	Diesel electric	500	400	200	D C	250	2	1	2–125 V gen. Single screw 1–250 V motor
1920	Crudoil	Tanker	Steam electric	1400	620	150–180	A C	440	1	2	Twin screw
1920	Elfay	Schooner yacht	Diesel electric	313	90	360	D C	125	1	1	Single screw
Building	Guinivere	Yacht	Diesel electric	642	550	220	D C	250	2	1	Single screw
Building	Powhaton	Passenger ship	Turbo Elec.	3440	3000	100	A C	1150	1	1	Synchronous motor
Building	4 ships	Coast guard cutters	Turbo electric	1600	2600	120	A C	1150	1	1	Synchronous motor
Building	United States Shipping Bd. 12 ships	Cargo	Turbo electric	9600	3000	100	A C	2300	1	1	Induction motor
Building	United Fruit Company	Cargo & Pass.	Turbo electric	6550	3000	100	A C	1150	1	1	Synchronous Motor

ANNUAL REPORT OF THE LIGHTING AND ILLUMINATION COMMITTEE

To the Board of Directors,

I BEG to submit on behalf of the Lighting and Illumination Committee the following report for the year 1919-20.

Activities of the Committee

Your Lighting and Illumination Committee, at its meeting on October 10th., 1919, decided to conduct a symposium on "Distribution Systems for Street Lighting" at one of the Institute meetings of the year, and to schedule, if possible, a paper on "An Analysis of Daylight Saving" at the Midwinter Convention. These plans resulted in holding the national meeting in Chicago on January 9th and 10th under the auspices of this Committee, at which three papers were read dealing with street lighting distribution systems. One of these papers on series systems was presented by W. P. Hurley, another, on multiple systems, by Ward Harrison, and a third, on constant potential series systems, by Charles P. Steinmetz.

The Chicago meeting was very successful and the discussions at both sessions were as complete as time permitted. At the afternoon session, prepared discussion was presented by C. H. Shepard of the Lincoln Park Board, Chicago; by N. B. Hinson, of the Southern California Edison Co.; by F. F. Fowle and W. F. Parker. In the evening, following Dr. Steinmetz's paper, illustrated discussion was presented by

F. A. Vaughn together with a description of the new group lighting system now used in Chicago for underground distribution for residence street lighting, by Deputy Commissioner Nixon. The newest things brought out in this discussion were the Chicago group lighting system and the conduit return system used in Southern California.

At the Midwinter convention in New York in February 1920, a paper on "Daylight Saving" was presented by Preston S. Millar under the auspices of the Lighting and Illumination Committee. This paper contained a comprehensive analysis of the subject and the general purpose kept in view by the author in the preparation of the paper is indicated by the following quotation from the opening paragraph of his remarks:

In accepting the invitation of the Lighting and Illumination Committee to present a paper on "Daylight Saving," the author stipulated that in order to consider the subject comprehensively, a considerable part of the paper would have to be devoted to matters remote from electrical engineering. The economic and sociological aspects of daylight saving surpass in importance the effect upon use of artificial light. Any treatment which should ignore these important features would lack perspective and would be likely still further to increase confusion on a subject which is greatly in need of clarification. Accordingly this paper includes a brief survey of daylight saving in its several aspects.

Your Lighting and Illumination Committee decided this year, as last year, to send a circular letter to the Chairmen of all of the Institute Sections, suggesting that one meeting of the year in each Section might profitably be devoted to an illumination topic. The following quotations from this year's letter will indicate the point of view taken by the Committee:

At the last meeting of the Lighting and Illumination Committee of the American Institute of Electrical Engineers held on October 10, 1919, in Philadelphia, it was decided to suggest to the Chairmen of the various Institute Sections that it might be desirable to include on the program for the current year one meeting devoted to some illumination topic.

Where the Local Section of the Institute is in a territory having a Local Section of the Illuminating Engineering Society it would be desirable in connection with the meeting devoted to illumination to have said meeting as a joint session between the two organizations.

The responses to this letter were widespread and a number of excellent papers dealing with various aspects of lighting and illumination were presented before some of the Local Sections during the course of the year.

Developments in the Lighting Field

Under date of January 16, 1920, the Chairman of the Board's Committee on Technical Activities sent a letter to the Chairmen of the Technical Committees, which contained, among other items, the following:

It was brought out very strongly at the last annual convention in the discussion of the Development Committee's report that the reports of Technical Committees should cover the activity in the particular line covered, so that anyone reading these reports from year to year would obtain a review of the progress of the art.

These reports should cover notable installations or developments during the year and it is suggested in view of the fact that in the past little has been done in this respect, that the reports might be a review of the state of the art up to date. One plan that was suggested which seemed to have considerable merit, was that the Chairman of the Committee might apportion to different members of the Committee certain parts of the field covered by the Committee's activities, and these should be edited and combined to be the report of the Committee.

Acting on this suggestion, the Chairman of your Lighting and Illumination Committee has addressed the members of the Committee in an effort to gather the important developments in the lighting field. These have been edited and combined so as to be the main portion of this report. It should be stated in advance, however, that the developments in the field of street lighting distribution, which were covered in the papers read before the Chicago meeting in January, will not be discussed in this report, since they will be found completely treated in the TRANSACTIONS of the Institute. The same statement applies to the important question of "Daylight Saving" which was covered in the paper before the Midwinter convention, and which will therefore be found in due time in the Institute TRANSACTIONS.

General Notes

As one of the results of the war, in its effects on the lighting field, a number of interesting papers have been presented during the past year. The titles of several of these papers will indicate the rather unusual character of the material which has been gathered under war conditions. Among these may be mentioned the following: "The Science of Marine Camouflage Design," "Painting Battleships for Low Visibility," "Camouflage," "The Principles of Camouflage" and "Industrial Lighting and its Relation to the War."

Following the war, the past year has witnessed an unusual increase in the interest taken in lighting in general. It has been felt that the past twelve months have, in fact, marked an awakening among the users of artificial light to its possibilities. This has been evidenced by the efforts made by various societies, organizations and associations, to have placed before them the facts as to what light can do in the way of increasing production, decreasing accidents and of improving the morale of employees in industrial plants. It would appear that a transition period is in progress in the lighting field, if one can judge by the trend of the developments during the year. Among these developments the following may be mentioned:

1. A widespread recognition of good lighting as an important aid to manufacturing.
2. The increasing use of the foot-candle meter as a means of checking illumination intensity in various parts of a lighted room.
3. Progress of industrial lighting codes.
4. Progress in automobile lighting regulations in several states.
5. Development of the bowl enameled Mazda C lamp to give better diffusion. The latest lamps of

this type have a feathered edge of the enameling to prevent a sharp "cut off" line.

6. The proposal of a plug outlet for permitting the convenient change of ceiling and wall fixtures.

7. The increasing tendency on the part of fixture manufacturers to make and advertise ready-to-hang types of fixtures. These fixtures are principally for commercial and industrial lighting but there is also some tendency to invade the residence lighting field, which seems to be an improvement both from the scientific and the commercial standpoints.

8. The formation of the fixture manufacturers association, with an attempt (as mentioned in item 6 above) to perfect a method of fixture hanging which will permit electric light fixtures to be hung as easily as a picture and moved, by the renter, as easily as a portable lamp can be moved, thus encouraging the renter to install improved fixtures as a substitute for bad designs often found to be in use when a house or an apartment is rented.

9. Progress in the enforcement of the industrial and automobile headlight codes. New York, Connecticut, California, Wisconsin and Pennsylvania have adopted the I. E. S. S. A. E. automobile headlight specifications, and it is reported that in all of these states, except New York, there are practical attempts at enforcement, which are gradually producing results that are favorable.

10. An important development in street lighting units is the "Duoflux" standard. This unit contains two lamps (in one type, one 1000 candle-power and one 250 candle-power) and by means of a relay located in the casing of the fixture, the 1000 candle-power lamp will be extinguished at midnight, and the 250 candle-power lamp lighted.

Developments in Lighting Units

The RLM standard dome reflectors have during the year become more widely adopted and nearly all the leading steel reflector manufacturers recommend these standards for industrial lighting.

Among the new fixtures and auxiliaries developed during the year, there may be mentioned the enclosing type of interior units which consist of a combination reflector, a diffuser and an enclosing globe in one piece. Another interesting development has been that of simplified units of the semi-indirect type, and the increased application of the incandescent lamp for moving picture projection. In street lighting, the single unit of high candle-power has quite largely replaced the cluster form of post, the former being considered superior both from the standpoint of efficiency as well as of appearance.

Luminous arc lamp efficiencies have been increased by the compounding under high pressure of the ingredients of the electrodes. It is reported that by this means, 30 to 40 per cent more light is produced than with the previous standard electrodes, with at least equal life. For the same light as formerly, increased life of the electrodes is expected.

Important Lighting Installations

The unusual lighting effects secured at the Chicago and the Buffalo electrical shows in 1919 may be mentioned. At Chicago, the so called "Palace of Aladdin" was housed in a structure 50 feet high, and interesting lighting effects secured with glass jewels, painted mirrored glass and flood lights. At Buffalo, 5000 *white* Mazda lamps were employed along with nearly 5000 illuminated disks distributed among the roof girders. The application of spectacular lighting of this general nature, was seen at its best, perhaps, in the "Jewel Portal for the Victorious Army" in New York and the "Altar of Victory" in Chicago. The use of 30,000 so called jewels in each of these remarkable lighting displays, contributed largely to the spectacular effects secured.

The effect of the war on industrial lighting has been to stimulate the interest taken in better factory lighting the past year. The tendency to employ illuminating engineers for the handling of industrial lighting schemes, rather than to entrust this work to the electrical department as heretofore, has been noticed. In one large industry a research is being conducted to ascertain the effects of lighting on production. The large increase in wages in the industries, with very little increase in the cost of factory lighting, has reduced the cost of good lighting in term of wage equivalents. This same fact has also made lighting the more important in terms of its effects on increased production and reduced spoilage.

A notable example of modern factory lighting installations is contained in a booklet recently issued by one of the lamp manufacturers. It would have been very difficult a short time ago to have published a book of this kind without relying upon the artist to touch out undesirable features and to paint in desirable ones. This entire booklet contains unretouched photographs of industrial lighting installations and is a commentary upon the improvements which have been made in this part of the illumination field.

In street lighting a number of important installations have been made. Among these may be mentioned the main street lighting in Salt Lake City consisting of 70 standards, each equipped with three 6.6-ampere ornamental luminous arc lamps. These units are spaced about 100 feet and the overall height is 29 feet. Although this particular system was put into operation prior to the current year, it represents an example of intensive street lighting which is coming more and more into prominence. More recent systems of intensive street lighting are the Triangle Lighting in San Francisco, first put into operation in January 1919, and the Broadway system in Los Angeles, put into operation in January 1920. The latter installation consists of 134 two-light ornamental

luminous arc standards 106 feet apart and 27 feet high. The installation cost was about $6.50 per front foot of property, and the annual operating cost is about $1.00 per front foot.

The Broadway system at Saratoga Springs is of interest in that about a mile of street is to be lighted by 69 of the new "Duoflux" units mentioned above. Each of these units contains two lamps, one of 1000 candle-power and one of 250 candle-power. This installation, which is to be put into operation about June 1920, will cost about $32,000 for its installation and for operation, about $10,350 per annum.

Contributions to the Art

Important papers contributed during the year include a discussion entitled "Coefficients of Utilization" by Ward Harrison and Earl A. Anderson, published in the March 20, 1920 issue of the *Transactions* of the Illuminating Engineering Society. This paper presents a method for the direct determination of coefficients of utilization applying to installations of all ordinary types of lighting units in rooms of varied proportions and different ceiling and wall colors. Actual colors for ceiling and wall surfaces covering 32 different shades with the corresponding reflection factors are included in the printed paper.

A paper on "Opportunities of Extending Lighting through New Applications" was read by R. M. Searle before the annual convention of the Illuminating Engineering Society in October 1919, which contains references to the following divisions of the lighting field: Street Lighting, Display Lighting, Flood Lighting, Lighting of Freight Terminals, Industrial Lighting, Stairway Lighting and Lighting for Community Affairs, this list giving an idea of some of the fields in which developments may be expected.

The following quotation from an address of President S. E. Doane before the Thirteenth annual convention of the Illuminating Engineering Society is of interest:

> The war has taught us that we have been regarding electric lighting, to use a phrase that one of my associates has given me, as a janitor service, whereas we should have looked at lighting as an item in the cost of production or in the cost of sales, and regarded it as any other factor in the cost. Then we would have examined, as have men within the last year or two, under what light we could get the maximum of visual acuity or speed of visual reaction. During the war time we have had some demonstrations. Mr. Durgin has given the most and the best of the practical demonstrations of how to apply this knowledge that visual acuity increases with the intensity of light and the speed of reaction increases production.
>
> Its application to production has been spectacular, and the results have been remarkable. As a matter of interest and as a measure of our opportunities I would like to use some figures from the lamp industry. Sixty-five per cent of the output of the lamp manufacturers, according to our estimates, is used in that portion of our business which would be affected by this knowledge. In other words, more than half of the electric lighting of this country can be affected and will be affected by the better knowledge we have of the production or increase in visual acuity and speed of visual reaction under intensive lighting.

For those who may be especially interested in the progress of the lighting and illumination art, attention is directed to the annual report of the Committee on Progress published each year by the Illuminating Engineering Society. The last report of this kind, covering 80 pages, will be found in the *Transactions* of the Illuminating Engineering Society for November 20, 1919.

C. E. Clewell, *Chairman.*

ANNUAL REPORT OF THE POWER STATION COMMITTEE

To the Board of Directors,

During the year 1919-1920 the Committee held two meetings, mainly devoted to discussion of papers presented, in person by the writers for comments and suggestions. The contributions to the activities of the Institute under the auspices of this Committee were as follows:

A symposium on steam turbine design, with the following papers:

- *Present Limits of Speed and Power of Single-Shaft Curtis Steam Turbines*, by Eskil Berg.
- *Present Limits of Speed and Power of Single-Shaft Steam Turbines*, by J. F. Johnson.
- *Present Limits of Speed and Output of Single-Shaft Turbo Generators*, by F. D. Newbury.

A plea for standardization in statistical records of state and governmental bodies reporting efficiencies of power plants, with the presentation of the following paper:

- *Essential Statistics for General Comparison of Steam Power Plant Performance*, by W. S. Gorsuch.

A symposium on excitation, with the papers to be presented at the Annual Convention as follows:

- *Considerations which Determine the Selection and General Design of an Exciter System*, by J. T. Barron and A. E. Bauhan.
- *Factors in Excitation Systems of Large Central Station Steam Plants*, by A. A. Meyer and J. W. Parker.
- *Exciters and Systems of Excitation*, by H. R. Summerhayes.
- *Application of D. C. Generators to Exciter Service*, by C. A. Boddie and F. L. Moon.
- *Exciter Practise in the Northwest*, by J. D. Ross.
- *Generator Excitation Practise in the Hydro-Electric Plants of the Southern California Edison Company*, by H. H. Cox and H. Michener.

The committee also considered the question of making suggestions for the activities of the incoming committee for the ensuing year, and recommended for consideration the following:

Safe Maximum Limit of Operating Capacity for Each Section of Bus.

Reactive Component Dispatching.

Auxiliaries in Steam and Hydro-Electric Plants.

Fighting Generator Fires.

Trend of Modern Power Station Design.

PHILIP TORCHIO, *Chairman.*

ANNUAL REPORT OF THE ELECTROPHYSICS COMMITTEE

To the Board of Directors,

THE Electrophysics Committee desires to receive suggestions for future work. It seems well, therefore, for this purpose to re-state from the report of last year the policy that this Committee has endeavored to carry out. It is as follows:

1. To encourage original papers of high technical standard, marking advances in electrophysics.
2. To have each year a broad, interesting, general lecture, free from mathematics, dealing with modern physics.
3. To promote a more complete cooperation and mutual understanding between the engineer and the physicist.

It is our object to keep open the "line of communication" between the pure physicist and the strictly applied physicist or engineer.

A joint meeting was held with the American Physical Society in Philadelphia, October 10-11th. The Physical Society session gave a notable discussion on the present status of theories of atomic structure. A review of this subject designed for engineers has been printed in the JOURNAL. The A. I. E. E. papers showed how these theories had been practically applied in the study of crystal structure and in the solution of vacuum tube problems. Other papers covered a variety of subjects marking advances in electrophysics.

Talks were given in an evening session by past presidents of the two Societies. It was the object of these talks to promote cooperation. The titles are significant—"The Indispensability to Each Other of Pure and Applied Science" by H. A. Bumstead; "Pure Science and Industrial Research" by J. J. Carty.

Additional technical papers have been given at other sessions.

F. W. PEEK, JR., *Chairman.*

ANNUAL REPORT OF THE TRACTION AND TRANSPORTATION COMMITTEE

To the Board of Directors,

TWO meetings were held under the auspices of the Traction and Transportation Committee; one at the mid-winter convention in New York in February, and the other at a regular meeting of the Institute in Pittsburg, March, 1920.

At the New York meeting there was presented and discussed a symposium paper entitled: "The Economic Supply of Power for the North East Atlantic Seaboard." This paper made reference to an item before Congress calling for a survey of the situation between Boston and Washington looking toward the establishment of a national policy in the matter of the generation and distribution of power through the means of which large economies could be effected as applying to labor, fuel and other materials.

The meeting passed a unanimous vote recommending that the Board of Directors of the Institute appoint a special committee to be known as the "Committee on Super Power System." This committee has since been appointed.

Since the above meeting, Congress has approved the proposed survey and appropriated $125,000 for the purpose.

The Pittsburg meeting included the presentation and discussion of papers relating to the design of the Minneapolis and St. Paul Electric locomotives by the General Electric Co. and by the Westinghouse Electric and Mfg. Co.; also papers concerning automatic substations and protection to substations.

Both of these meetings were largely attended and much valuable information and data were presented, all of which has appeared or will appear in the TRANSACTIONS.

There seems to be no disagreement on the part of any members of the committee in the Conclusion (1) that Super Power Systems stand as future guarantors for economical generation and distribution of power and (2) that the electric locomotive has demonstrated its ability as applying to passenger, freight or switching movement, to outclass the steam locomotive in capacity and control.

WM. S. MURRAY, *Chairman.*

DRYING FLOODED ELECTRICAL EQUIPMENT

A description is given of the methods employed to dry out an electric generator, switchboard and motors which had been under water for more than a week in a flooded basement, the water being contaminated with sewage and sludge.

A corrugated sheet iron house was built round the generator and engine, and two wood-burning stoves were placed inside this housing. A temperature of about 90 deg. cent. was maintained for five days and nights, by which time the generator was fairly dry except for moisture inside the V-rings of the commutator. This moisture was removed by heating the commutator itself, the generator being run with the shunt field disconnected and the armature short-circuited through the series winding. This stage in the process occupied a day and a half. The switchboard instruments were returned to the maker. (K. A. Reed, *Power*, Feb. 17, 1920. 3½ cols., 2 figs.)—*The Technical Review.*

Discussion on the Super Power System for the Northeast Atlantic Seaboard

Presented at the Midwinter Convention of the A. I. E. E., February, 1920

W. S. Murray: It is certainly a great pleasure and honor to stand up before such an excellent gathering of my brother engineers. I do not think that we are here today to discuss the technical features of power generation, transmission, traction, and all such problems of electrical engineering with which we are so familiar. If I could accomplish the real objective of my standing before you today, it would be to infuse in you something which I believe to be right and something that we should do.

Power, to my mind, is the father of accomplishments, moral, intellectual and physical. That statement can be qualified in a great many ways, but I think you know what I mean. Electricity is power's greatest agent. Good business succeeds if it has good agents; poor business fails when it has poor agents. Electricity is the greatest agent of power, it is power's greatest sales agent.

Did you ever realize what would happen if, overnight, for instance, iron lost its magnetic properties? It would mean that practically every steam turbine and electric generator, of over two thousand or three thousand kw. in capacity would be scrapped. Ninety five per cent of the power apparatus of this country would go out of business. Now, what does that mean? That means simply that electricity is power's greatest agent. In other words, electricity is the greatest agent in the world as a power distributor. When electricity appeared, it went in front of and behind the prime mover—it went behind the prime mover, because it increased tremendously the economy of power production, and it went ahead of the prime mover, because it eliminated the wasteful jack-shafts, belts, etc.

Now, where is its field? Its field can be divided up into five distinct parts: Industrial establishments; street railways; heavy transportation, including passenger, freight and switching service; light, and miscellaneous applications—those five. With these in mind, it should be our endeavor in every possible way to erect the channels through which electricity may flow into its rightful field, and, per contra, to erect barriers to prevent any other form of power getting into that field.

I believe if we constantly keep this in mind that we will secure a proper application of power, with electricity as its agent.

I have thought and talked a great deal about the super-power system. It has been presented on the pages of the technical and public press. I do not think that with as many splendid men as we have here who will contribute to this discussion, that a great deal of time should be taken in the description of the super-power system. I believe you all pretty well know what it is. To brief it, the idea is that in a zone between Boston and Washington, and about 100 to 150 miles in from the coast, there exists today a machine capacity, railroad and industrial, of about 17,000,000 h. p.—of which 10,000,000 is industrial and 7,000,000 railroad. The load factor in that zone is certainly not more than 15 per cent. By the installation of a system of transmission lines and radials, these users of power will be connected to power stations of high economy, constructed at tidewater at proper coaling points—to steam generating stations erected where economy predicts, at the mouths of mines, and to river stations where hydro-electric plants offer opportunity of economic development, all of these stations to be interconnected with a high voltage transmission system as previously mentioned.

It is my conclusion, as judged from general investigation, that the number of pounds of steam per kw-hr. used today throughout that zone which I have described is about 40 on the average. Prof. Breckenridge of Yale University thinks that I am too conservative on these figures. However, let us take it at 40 pounds of steam. With steam generating units of from 35,000 to 50,000 kw., this average rate will sink to 15 pounds of steam per kw-hr.

The load factor of the zone will be lifted from 15 per cent to 50 per cent,—I have seen opportunities in connection with my work on the New Haven of securing a 75 per cent load factor—and this means that we will conserve capacity to extent of three-fold, and our natural resources in the form of coal, and fuel oil, two-fold. There will be a large amount of money required for investment to accomplish this but as far as I am able to determine it, based on even the high prices we are living under today, the return will be $300,000,000 a year and this represents something like 24 per cent on the investment.

I think that that may give you a brief sketch of the super-power plan. I might say that prior to the war, the idea of a consolidation of the roads on the west side of the Hudson River seemed a very attractive field for economic returns; their operation being planned under what might be called a General Power and Equipment Company—the occurrence, however, of the war, made it impossible to carry this thought further. An idea began, however, to rise in my mind as to the possibility of an extension of these principles to a larger zone. Indeed, gentlemen, first to the house, the city, then to the district, and as certainly as I am standing up here before you, you are going to see just this thing happen that I am describing to you. It has got to be. You cannot stop it. Not to stop it means that we engineers who stand for conservation, must say "We know it, we know that there are $300,000,000 a year going to waste and assimilate the slur too often cast upon this country that our waste is enough to keep three of the biggest European powers going, and I believe that is a fact."

What is the plan? It is an investigation or survey on the part of Department of the Interior to allocate,

these wastes with recommendations for a regional plant by which they can be eliminated. There is an appropriation in the amount of $250,000 forming a part of the Sundry Civil Bill to be presented to the Committee on Appropriations between now and the 30th of June, with which to make this investigation; in other words, we want to spend $250,000, with which to point out the way an annual saving of $300,000,000 can be made.

Now, I have taken more time than I intended in presenting this matter to you. The men who have designed our turbines, and our generators and who know what transmission requirements are that large bulks of power at high efficiency may be transmitted, are here today and I have talked to them, as I have tried to develop the subject and they have encouraged me to believe that I am on the right path. They have created these engines and apparatus of economy and so made the super-power system possible.

It seemed advisable therefor to have the authors on the subject of the parts of this regional zone give us the benefit of their opinions. To that end a circular letter was written to Mr. W. LeR. Emmet, Mr. J. F. Johnson, Mr. H. G. Reist, Mr F. D. Newbury, Mr. W. B. Potter, Mr. Philip Torchio, Mr. Percy H. Thomas, Mr. W. D. A. Peaslee and Mr. A. O. Austin—these men representing, as I have explained to you, large turbines, large generators, heavy traction machines, transmissions, and insulation, all of these being parts of this great system which will be necessary to its successful operation.

Now, I shall not discuss my symposium nor the papers by the several authors, because I want to see most of these men on their feet here, so that you may listen to *them* and hear what they have got to say, and then I would like to hear from others who may have some contributions to make, and the only thought I want to leave with you is this—Prof. Scott has pointed out in an address before the National Electric Light Association that if the rate of increase of power in New England is sustained, as it is going on today, that in ten years' time the amount of power required there which is now 1,500,000 kw. will be 5,500,000 kw. That is merely in New England. All of the dense districts along the Northeastern Atlantic Seaboard are now or will be like that, and so it is not a question of how are we going to take care of this immediate future—why—the immediate future is right here—the foundations for this tremendously increasing density must be laid now for we cannot perpetuate these old methods of the past, which will only mean that as density increases the losses of today are to be increased; and so I want to leave with you this thought—that this is something that we must do and do *now!* Every *part* of it has been done. It has not been put together. That is all. We have got to start right now, and put this great regional plant together, and be ready for this expansion which is now upon us.

One other thought—one of the things that has militated terrifically against our industrial expansion is that we cannot get our materials over the railroads. Now, the installation of this proposed system will be a relief to the railroads. It means the creation of an overhead common carrier system of power, and that means that the coal that is now clogging our main lines, sidings and yards, can, in a large measure, be lifted off the rails of the steam railroads, and that will automatically create cargo space for other and higher priced commodities, thus yielding an increased return, and it also means, as any man knows who has been connected with the electrification of railroads, that the capacity of the railroads will be tremendously increased. Take the switch engine, for example. We put seven switch engines in the Oak Park yard, and they did the work of ten steam engines and speeded up the work fully 50 per cent. One of these switch engines went 40,000 miles before it had a commutator turned,—before it had anything done to it other than its routine inspection.

We have arrived at the time when we know what electricity can do for the railroads and industries in the way of cutting down this frightful coal bill, and conserving our natural resources, and opening up traffic for other and higher priced commodities, and saving enormously the maintenance cost of power machinery, both on the railroads and in the factory; but the people do not know it, and we have to educate these people so that they do know it.

Now, gentlemen, I will call on Prof. Malcolm Maclaren, of Princeton University, who has made a study of the Southern District through the War Industries Board of this proposition, and he can bring you very closely in touch with the very excellent contributions that that board made to the government during our strenuous times. We would be glad to hear from Prof. Maclaren.

Malcolm MacLaren: By way of introduction, I would like to testify to the splendid work our Chairman is doing in the cause of conservation, which is of such vital importance to us nationally in the industrial expansion which we are hoping will take place following the war. It seems to me, as we have one of our own representatives engaged in this work with such tremendous enthusiasm and with such wide vision, that it behooves every member of the Institute to co-operate with him to the full extent of his power.

During the late war I had occasion to devote most of my time to a study of the power conditions along the Atlantic Seaboard and I became very much impressed with the opportunities for procuring great economies through more extensive interconnections between systems and more effective utilization of the natural resources of the district. If the war had continued, the Government would have assisted in carrying out improvements along these lines and important developments were maturing when the armistice put a stop to the work. This need, however, is still present and is possibly even more pressing than before as a purely economic measure. With the inceasing shortage of fuel and labor, the wasteful isolated industrial steam plants should be abandoned in favor of central station power, the electrification of the steam railroads should be extended both as a conservation measure and in order to obtain increased capacity with the minimum expenditure of capital, and the power companies in their expansion to meet their increasing demands for power should seek to utilize to the maximum the natural resources available in order to maintain a cheap and reliable power supply.

On account of the magnitude of the problem and the number of varied interests involved, it is essential, in order to obtain the best results, that some independent body make a careful study of this situation, and I believe the Institute could render no greater service to this community at the present time, than by urging the creation of a commission which should direct the course that these developments should take.

In a few minutes which are allotted to me I will not attempt even to outline the scope that this in-

vestigation might take, but will confine my remarks to the consideration of the needs of only one portion of the territory under consideration; namely of Eastern Pennsylvania, New Jersey and New York City. There are four more or less distinct industrial districts within this area; one includes Philadelphia and extends along both banks of the Delaware River from Chester to Trenton; another centers about Newark reaching from Paterson in the north to Perth Amboy in the south; the third is comprised within the limits of Greater New York, and the fourth includes the anthracite coal fields extending south to Allentown, Bethlehem and Easton, which may be designated as the Lehigh District.

In order to form some sort of a picture of the possible future power requirements for this territory, I recently made a rather careful analysis of the demand which would occur at present if all of the industrial load of each district were carried from a single power system and if all the steam railroads within same areas were electrified and served from the same system. From the nature of the case the figures must be considered as approximate but I believe that they are based upon sound premises and are reasonably correct. The results show that for the Philadelphia District the maximum demand would be approximately 700,000 kw. For the Newark District 550,000 kw. For the Lehigh District 650,000 kw. No estimate was made for New York, but its demand would be probably not far from 700,000 kw., making a total of 2,600,000 kw.

The public utility companies within this territory are now carrying a little less than 1,000,000 kw. of this total. Without attempting to study the rate at which the power companies are taking over this load and providing for new industries, does it not seem reasonable to expect in the light of the above figures that the demand upon these electrical systems within the next ten years should reach 2,500,000 kw., provided a unified system is developed which takes full advantage of the natural resources of the district? The generating facilities of the power companies already developed or contemplated by present construction programs will provide for carrying about one-half of this load, leaving over 1,000,000 kw. additional to be furnished. The most promising methods for obtaining this additional capacity are:

By hydroelectric developments on the Susquehanna River.

By hydroelectric developments on the Delaware River.

By construction of steam plants at the anthracite mines.

The largest single development projected for the Susquehanna River covers the construction of an hydroelectric installation at Conowingo near the mouth of the river which will have an initial capacity of 125,000 kw., and will be capable of producing approximately 700,000,000 kw-hr. in a dry year. This is somewhat less than the present annual production of the electrical systems of the Philadelphia District, where it could be most readily used, but as it is river flow power varying in amount with the seasons and river stages, it could not all be absorbed by these systems until their loads have increased or more extended interconnections permit of a wider distribution of power. This 700,000,000 kw-hr. represents only about one-third of the energy of the river at Conowingo, and with a relatively small amount of river control it should be possible to increase the output at this point and develop other sites which should yield between 200,000 and 300,000 kw. and 1,500,000,000 kw-hr. annually.

Plans are well advanced for the development of a series of hydroelectric plants on the Delaware River which indicate that it would be feasible to utilize a very large percentage of the total energy of this river and that complete river control might be obtained without excessive cost for reservoirs. Such a system would be capable of producing 250,000 kw., of primary power and 1,000,000,000 kw-hr. annually.

Considering next the construction of the steam plants in the mines, it should be noted that it may not prove feasible in the present state of the art to install in the anthracite region super-power plants of 300,000 kw. or more such as have been proposed for other districts, as there are few if any sites in this district where there is combined an adequate supply of the smaller sizes of coal with water conditions suitable for operating a plant of such magnitude. It is probable therefore that steam plants which may be constructed in this region within the next few years will be of less individual capacity, but of sufficient number to meet local needs and furnish considerable surplus for transmitting into adjoining territory.

Purely as a conservation measure it is important that such plants be constructed at an early date for by thus increasing the demand for the smaller sizes of anthracite the conversion of these mines to electric operation should be greatly stimulated. It would be difficult to find a better illustration of the economies to be derived from the use of central station power than can be shown in this case, where heretofore there has been a most extravagant use of fuel because the smaller sizes of coal have been utilized for which there has not been a ready market. The Report of the Bureau of Mines for Pennsylvania shows that for a total annual production of 80,000,000 tons of anthracite for this district over 8,000,000 tons were used in the mine operations. Data obtained from the electrified mines of the district indicate that if all the mines were electrically operated from a central supply system this 8,000,000 tons now being used for mining coal, would be capable of supplying all the needs of the coal companies and have a balance sufficient to operate a generating system of over 600,000 kw. capacity at 50 per cent load factor, or approximately the entire power load of Greater New York including the railways.

The picture, which might be formed of a general scheme to be followed during the next ten years to meet the growing need for power within this territory, is that the power companies in the large cities should in general complete their present construction programs but should not greatly increase their generating facilities beyond this point, additional capacity being obtained by the construction of steam plants at the mines, reenforced on the east by hydroelectric plants on the Delaware River and on the west by hydroelectric plants on the Susquehanna, the whole territory being interconnected with transmission circuits. Such a system should produce a cheap and reliable source of power under normal conditions and would have the greatest flexibility for meeting emergencies, for the generating facilities would be divided in approximately equal amounts among steam plants at the large cities burning bituminous coal, steam plants at the mines burning anthracite and hydroelectric plants on the Delaware and Susquehanna Rivers; the unified system of transmission circuits making it possible to

transfer larger blocks of power to any point in distress without the use of rail transportation.

W. S. Murray: I am going to take the opportunity, unless the meeting should object, to intersperse one or two remarks between the authors' statements. I have found it difficult to describe so large a thing quickly, and you appreciate that it is quite possible in such a presentation to miss a great many things. At least keep in thought, however, that in the development of this zone, the available water power in the district looks as if it would not supply more than 10 per cent of the total amount of power required, and that later as the power requirement increases that percentage may be even less.

I do not know how near my figures may be correct but I question today, with the present labor and coal rates in New York City, whether a kw-hr. is produced for less than ten mills, may be eleven mills.

The Delaware River, fifty five miles from here, supplying a billion kw., which I understand can be placed in New York for somewhere around five mills, would show upon that basis a saving of $6,000,000 a year, thus it is important to keep in mind, though the hydroelectric power is small, that it be included in this great system, and because it is small, as I think Mr. Torchio will bring out later, its application is the easier and more efficiently made.

We have with us Mr. Riest, of the General Electric Company, who has made a contribution to this symposium in connection with large generators. I would like to say, as there is a very large number of men whom I would like to call upon, that if the speakers can condense their remarks better than I have done, I will appreciate it.

H. C. Reist: I think perhaps I will save time if I read the paper as it is printed.

(Mr. Reist read the paper).

W. S. Murray: It is, indeed, reassuring to have a man like Mr. Reist on his feet, telling us that the generator part of this system is ready. I do not think I need to introduce Prof. Scott to this audience.

C. F. Scott: Mr. Murray has a way of taking a super view of things; he is constituted that way and he cannot help it. On the New Haven Road a few years ago he had vexing problems with control wires and circuit breakers and details of daily operation, but he kept thinking of something else, of transportation in its largest sense. Later he operated a power plant and built a hydroelectric station and he had problems, of operating accounts and of foot-seconds and dams and transmission lines. But he began to think of combining power plants into a great power system to serve electrified railroads and industry; he has visualized into a super-power system all the things he has ever had anything to do with.

In our Institute records there are papers describing what we have accomplished and what we are doing and how we may do things. Here is a paper that looks forward in electrical engineering, not in theoretical research but in the service side of engineering. The vision is large; it involves too much to grasp. It is a difficult problem to get other people to understand what engineering has done and is doing and can do. I must take exception to Mr. Murray's statement that nobody understands these engineering matters except ourselves; I question whether even engineers really realize what is going on and what our accelerating rate implies.

What have we been doing in the past? What is our rate of progress? It is not quite fifteen years since we came into this building. What has been going on since then? We thought that engineering was pretty large then, but in the short interval some startling advances have been made. The annual output of the industries of the country have doubled. Our railway freight transportation since Mr. Murray began to run electric locomotives on the New Haven (which was three months after we dedicated this building) has doubled, *i. e.*, the ton miles of freight haul is twice as great; railway trackage has increased a little, but trains are longer and cars are larger and even then the augmented service scarcely meets the requirements. Industry and transportation have increased as much in a dozen years as they did in the previous century.

The use of electricity by the rule of the past doubles in about five years. Since the date of the electrification of subways and railway terminals in New York, since this building was completed, the use of electricity has increased fivefold; five times the kilowatt-hours are produced now that were produced a dozen years ago.

Consideration of this remarkable rate of increase takes the things which Mr. Murray plans out of the indefinite future and puts them only a little way ahead on the projection into the future of the curves of past performance.

As we look into the power problems in a new way surprising things appear. Professor Maclaren mentioned one a few minutes ago when he said that the first thing that is done with coal is to burn it at the mine's mouth for operating the mines. Prevalent methods involve such a waste of coal that the same coal which is now used could be burned in efficient power plants and would furnish enough electric power for operating the mines with a surplus sufficient to replace all the power plants which are now supplying New York City.

In transportation we ordinarily think of the railroad as the only important factor. But the cost of local transportation of freight for a few miles or even a few blocks in a city is often equal to the cost of transporting it 500 or a 1000 miles by rail. The present problems in transportation are at the terminals. A prominent terminal engineer predicts that the amount of electric appliances which will in future be used in the handling of freight at terminals will exceed in cost the electric locomotives which will haul it across country.

The super-power system is the goal toward which we have been tending. Engineers used to deal with the problems of making motors, generators and turbines that would run; then came problems of transmitting power. Small isolated stations gave place to larger power houses and extended systems. Then came problems of application and the use of power. A difficulty in the past has been to get the public convinced that it was worth while to use electric power. The public has learned to use power and now the great problem is the universal supply of power for all purposes.

W. S. Murray: Prof. Scott's reference to Prof. Maclaren's thought of using electric power in the mines leads me to tell you that in Logan County, West Virginia, some years ago, the amount of power in boilers scattered around the mining properties, to handle the mining processes aggregated 4000 h. p. Some bright electrical man went down there and built a central station, and gathered upon its feed lines the connections to these mines to operate them

by electricity, and when he found out what the total demand was to handle them all it was 500 kw.—it was an eight to one proposition.

Now, I say this zone to which I have referred, is nothing but Logan County multiplied 5000 times.

We have between the covers of this symposium what I consider an epoch-making presentation. I cannot find quite the words, they are in my heart all right, but not in my mind, to introduce the man who will speak to you now. I know what I want to say, but cannot quite say it Maybe I better say what was said to me of him—"Thomas, yes, a brilliant but an entirely practical man." Mr. Thomas, we would like to hear from you.

Percy H. Thomas: I have considered the problems of transmission and distribution in the super-power plant from the broadest point of view, putting emphasis on the elements which may call for new methods and variations from the usual practise. In some ways transmission and distribution are the most difficult to treat of all the problems involved. The conclusions are so fundamental. The question as to whether coal should be burned at tidewater and near the consumption centers or whether it should be burned where it occurs or near there, and transmitted over transmission lines, remains yet to be settled. I have at the direction of our Chairman, practically assumed for the purposes of this discussion, that the power stations should be located near the mines and the power transmitted,—that is to say, I have presented the best case I can for the *transmission* of the power.

In assuming the mine location for the power, I have not overlooked the matter of condensing water, for the importance of cooling water for condensers for the steam units is frequently emphasized, and surely, it is of great importance. However, I feel sure that with a radius of thirty or forty miles from any coal region we could perhaps find a site or group of sites in which this fundamental problem can be solved. It is not really as fundamental as some of the other factors. Perhaps, we will have to make a large lake, and use the water over and over, use natural or artificial cooling, but I do not propose to go into that subject at the present moment.

Referring to the general scheme here proposed Fig. 1 shows a typical transmission line that might be utilized for tying together the whole district. The numerical values I have given as to cost and regulation are based on this system. It is an advantageous layout in that all the principal centers are tied by a tie which does not regularly transmit large bodies of power for a long distance in any one direction, but only interchanges power, partly primary power from the coal fields, and partly emergency power from those plants near any point in distress. It would enable, for example, the output of a couple of large units installed in Newark, to be used for a new load in Philadelphia, until after awhile perhaps Philadelphia had installed some units of its own and vice versa.

I think you will agree that the operating characteristics of a system like this shown in Fig. 1 would be relatively very favorable. This is, of course, a most important matter when we come to tying the whole super-power plant district together.

The dominating question which I think is going to determine whether it is better to burn coal at the distributing centers or near the source of supply, will be the first cost of the necessary transmission line to transmit the power if we burn at the mine mouth. This is determined by the cost of the physical structure, in the first place, and secondly, by the capacity of that structure. Therefore, I have done my best to get a favorable solution from both points of view, as will appear in the paper.

To make the case a little more concrete, I have assumed we would start perhaps two years from now, on the theory that new load hereafter connected in this whole district would be carried by the installation of new power plants at the soft coal and hard coal districts, and at a later period by some large hydro-electric supply, as from the St. Lawrence River, or possibly from Niagara Falls. This would permit the now existing systems to regulate voltage and take care of distribution and things of that sort, and would facilitate the step by step introduction of the new scheme, starting with the existing situation. To give the most favorable justification for building the high voltage lines as shown in Fig. 1, I have assumed they would be built and extended from time to time to the point that their capacity would be approximately equal to the maximum 24-hour demand of the district, so that these stations could run 24 hours a day. Then the existing plant in the present power stations would be used for the load peaks and emergencies. It is surprising how small an addition to the group of existing plants a large power plant, 300,000 or 400,000 kw. appears to be.

There does not seem to be any hope of using a higher delivered voltage than 250,000, and I have taken that value. I believe, by the time such a system could be developed that this voltage could be suitable, so my discussion assumes the delivery of 250,000 volts at the distribution points, which means 275,000 to 280,000 volts at the generators. This is one voltage step beyond the 220,000-volt group which we are now prepared to deal with in actual installations.

I calculate that a line can be built with a single circuit of three wires, that would transmit 400,000 kw. for 150 miles with an energy loss of about 5 per cent, and a regulation, that is a drop in voltage at full load, of approximately 9 per cent. That is based on the assumption that the load will be delivered at 99 per cent power factor lagging. Ninety-nine per cent is not the power factor at which the load can be most easily absorbed, but it is very helpful to the transmission line, and I am inclined to believe that the most satisfactory working out of the system as a whole will be to so modify the distributing plants, if necessary, that they can absorb power at this power factor. When you consider the inefficient steam units that can be shut down, leaving the generators as synchronous generators, and the new applications of power which perhaps can be supplied in such a way as to have a leading power factor, for example, the railroad, I am not so sure that the securing of this power factor may not be a relatively easy matter.

This line I have been describing has a rather interesting characteristic. If you short-circuit one end, and maintain voltage at the other, it will pass only four times full load current, and this without taking into account any current-limiting effects of transformers or generators. This fact was a great surprise to me at first, and I think it will be a surprise to a good many others. You can see the great operating help it will be, however, in linking together a number of these stations. It removes one great objection to carrying the idea of a super-power plant a little further, if, for example, we should ever interconnect Niagara Falls and Buffalo and Pittsburgh, and a large

number of other stations widely scattered, it would be possible to have a short circuit at any one point that would not affect other cities one or two hundred miles away, because the interconnecting transmission lines would for the time being maintain a drop equal to the full line potential and without a flow of current which would either destroy them immediately, or be beyond the power of circuit breakers to open. This is a feature of much practical importance.

The full load loss in line is at a minimum when the delivered power factor is practically in unity, and that is the reason for assuming the power factor as 99 per cent in my discussion. The line drop depends primarily on the self-induction. The effect of self-induction is electromagnetic, one-half the square of the current times the reactance of the line represents a certain amount of energy which goes into the magnetic field around the wire, and comes out again a half-cycle later, and must be supplied from the generator, but is never delivered to a load. It lags 90 degrees from the voltage. In a high-tension transmission line energy passes also into an electrostatic field supplied by charging current; that is, there is a second flow of energy from the generator which never gets to the receiving end, which is stored in the electrostatic field. This flow is exactly opposite in direction to the lagging flow with unity power factor. As a matter of fact, if the transmission line is so proportioned and the load and voltage on it so chosen that these loading and lagging quantities are equal, they disappear and the generator is not called upon to supply either one.

The net results is that the current that flows transmits energy practically the same as if it were direct current. This is exactly accomplished only with unity power factor, because only under that condition is the energy which goes to the magnetic field exactly opposed in direction of flow to the energy in the static field. When you remember that with the conductors I have chosen here the reactance is something like seven times the resistance, the effect of eliminating the influence of reactance on regulation becomes very important. It is necessary only to increase the section of the conductors to get any desired reduction of the loss of energy in the line. The transmission line circuit of Fig. 1 which carries 400,000 kw. has three conductors in each phase, 600,000 cir. mil. aluminum (with steel core) or it might have the equivalent in copper. This balancing of reactance against capacity shows why on short circuit this transmission line will not give an excessive current. On short circuit the voltage largely disappears—that means the static energy, the energy which goes into the electrostatic field and which has been relied upon to neutralize the energy stored in the magnetic field, has disappeared, and the predominant effect of the reactance factor is established; except for the line capacity, the full regulation of this line would be of the order of 20 to 30 per cent. We could not get 400,000 kw. from a circuit with this amount of conductor.

I have assumed that the line conductor in any phase which would normally be a cable about two inches in diameter, is divided into three parts, these three parts being separated by perhaps eighteen inches, making nine wires for the single three-phase circuit, three in each phase. That separating of the cable into three parts has the effect of reducing the reactance, as you can see, and this is a well-known expedient in other applications. It has also the effect of increasing capacity in approximately the same ratio. It also has the effect of raising the corona limit.

While I have not determined exactly the factor by which the capacity is raised, and the reactance lowered it can be made in the neighborhood of 0.6. In my calculations I have assumed that the reactance of the three wires separate is 0.6 of the reactance that would exist if they were in one single conductor, and similarly for the capacity.

The reactance being smaller, lowers the amount of energy stored in the magnetic field, and the capacity being larger increases the amount of energy stored in the electrostatic field, and as a result, to get a condition in which one balances the other, it is necessary to increase the load inversely as the square of 0.6, and that is, it increases about three times the load that is necessary to put on the line, to get the ideal balance conditions of reactance and capacity, so that in the case of the line which with the ordinary use of the same weight of conductor would have its limit at 125,000 to 150,000 kw., by this expedient has its limit at about 400,000 kw.

The mechanical features of the line are important. How will this division of conductors into three parts affect the behavior? These mechanical matters must be worked out in detail, and they surely can be. It is only a question of cost, which we cannot stop to consider now.

I have assumed, and here most of you perhaps will differ with me, that no spare transmission line will be provided. This would greatly reduce the costs of the original installation, and it would also greatly reduce the complication of switching. In justification of this omission of a spare line, it may be pointed out that there occur occasional disasters which deprive local districts of the use of present power house systems temporarily, or the railroad service, but the community nevertheless, succeeds in getting along one way or another. Personally, I am inclined to think so far as a breakdown on one of these transmission circuits would disturb the community it is better on the whole to makeshift than to attempt to give absolute continuity of service. The failure of a line would at the most cut off only 20 per cent of the total power of the district, and since power can be passed backward and forward anywhere in the load district, this failure must occur on the peak to cause an actual shortage.

There is one thing to which I would like to call your attention—if New York and Philadelphia are connected by a high voltage line in order that in case of breakdown in Philadelphia, New York will supply a couple of hundred thousand kilowatts, or vice versa, the flow of energy between these cities should occur without any material change of voltage, because if, when transmitting power from Philadelphia to New York, the voltage was 10 per cent higher in Philadelphia than in New York, it would follow that when transmitting the power in the reverse direction, the voltage at Philadelphia would be 20 per cent lower than normal, which could not be satisfactory. With the line here proposed, in which the reactance is high, and the resistance is low, it is possible to transmit power in either direction in large quantities without altering the voltage on either end. This is done by changing the power factor of the energy which flows—raising the generator field current at New York will tend to raise the New York voltage and make up for ohmic drop due to energy flow from Philadelphia. There is no new principle involved here, and if you will make the calculations by the well-known formula, you will find that there will be no difficulty in main-

taining a higher voltage at the receiving station than at the transmitting end.

This is a very favorable condition. It means that each center, Philadelphia, New York and Baltimore, can maintain its own voltage as may be desired, and the power can be transmitted automatically either way by a suitable combination of governors and field regulators, working on the field currents of the main generators in each center.

I have made some rough estimates as to what this system would cost, *viz*: $164.00 per kw. including generating equipment for 800,000 kw. with 12.5 per cent spare capacity transmission, and interconnecting tie lines, transformers and switches. Of that $164.00, $100.00 is for power plants.

If a power plant be located in a large city on tidewater, especially if it is a city like Philadelphia, I think the cost would be something like 25 per cent greater than for a power plant built on some favorable site away from city conditions. This is partly because on tidewater, foundations are usually very expensive, and because power must be distributed through underground cables with the high tension line, there will be a new point of contact with the distributing system.

W. S. Murray: Mr. Thomas has visualized to you what I could not so well do, because of his intimate knowledge of transmission facts. He is bringing the districts together, he is building the thing right before your eyes—the expansion from house, to the town, to the district, and now to the region. He has left with you the thought of power stations separated by hundreds of miles yet with losses between them of only five per cent, through this wonderful interrelation of capacity and inductance. It must be as clear to you, as it is to me. It puts stations widely separated next door to each other so that there develops before our eyes not so much the advantage of diversity factor, which we hear so much about—of course, diversity factor is important—but what is going to count to a still greater degree—diversity economy.

How often have any of you had the experience of having to operate low economy machines when there stood idle in the next district a machine with an efficiency equal to your most economic machine. The advantage of diversity economy is in picking the high economy machines out of any station and placing them on the zone bus. That is what we want to get. Get this great industrial district tied together. Mr. Thomas has touched on one of the most important points in the whole thing, and that is why we were all delighted to have him take so much time. I ask if Mr. Johnson is in the room? I fear he was not able to be with us. We have not had any discussion with regard to electric traction, and Mr. Storer has honored us with his presence, and I am going to ask him to make a few remarks, and as our time is passing rapidly, if he will confine himself to about ten minutes, I will appreciate it.

N. W. Storer: Mr. Murray in his symposium has referred to a paper which I presented a couple of months ago in Chicago before the Western Railway Club, on the general subject of Electrification. I touch on electrification, because that is the only point from which I can approach this paper which has been so admirably presented. Electrification means conservation of fuel and labor. At the present time we are in need of both. The United States was never so short of labor as it is right now, and I see no chance for the situation to be made any better in the near future.

Now, the railways, as I have said before, need to take a leaf from the experience of the housewives of the country. They must "do it electrically." You will find in every household in the country, the introduction of electrical appliances wherever the power supply is available. These are installed to save the labor of the housekeeper and they do it. Of the multitude of appliances which are put in now, one who is not a housekeeper can scarcely begin to think.

If the railways would electrify, they would find the same reasons for so doing, find just as great economies in labor as the housekeeper does,—they would find not only that their motive power costs less, but that at other places along the line, where power can be substituted for manual labor, it should be done, and can be done with much greater economy than they can possibly do it with manual labor.

Railways simply are not able to get labor at the present time. That means they cannot give us the transportation. It cannot be done at the present stage of the labor market, and unless they are able to go ahead and make some changes in their system, such as by electrification, they never will be able to give us what we need in transportation, and that means the greatest handicap that can be put upon the prosperity of the country. Now, the question of the conservation of fuel has been touched on very thoroughly, and I only want to refer to it briefly. In my Chicago paper I quoted from other authorities, the fact that possibly two-thirds of the fuel now used by the steam locomotives could be saved if the railways were electrified. A representative of the Fuel Administration questioned that—he wanted me to show him the figures. I had not the figures at hand at that time, but I went at it after I got home, when I had a little time, and the result was that I was more than ever convinced of the truth of that statement.

I was especially convinced of it after reading a paper by Mr. Muhlfeld, an ardent advocate of the steam locomotive, in "The Railway Age". In that article Mr. Muhlfeld, gave figures showing the coal and water consumption of steam locomotives and their auxiliaries which, to my mind, would condemn the whole system. It was no trick at all to take his figures and show how the electric locomotives would save two-thirds of the fuel. He said that the present steam-driven air compressors on the locomotives took from 70 to 85 lb. of steam at 200 lb. pressure to compress 100 cubic feet of free air.

Now, that is anywhere from seven to ten times as much power as would be taken to do that same work with an electric motor. It is an extremely wasteful proposition to do it with the ordinary single-acting compressor. He was pointing out where they could save energy by substituting a cross-compound compressor which would save probably one-half or possibly two-thirds of it, but still the power taken by these auxiliaries is enormous. Just that air compressor with 70 to 85 lb. of steam for 100 feet of air, amounts to something like 150 or 160 h. p., and maybe 200 h. p. It is not, as I repeat, a difficult matter now to show that the electric locomotive will do the work, and do it better, with one-third of the fuel that is now used by the steam locomotives.

W. S. Murray: Gentlemen, we have on our list here one who has contributed a wonderful paper to this symposium, one whom we have reason to admire

and respect for his splendid operating experience. I have always maintained the ground that after all this proposition is but an expansion of the central station business. Some have the idea that the super-power line was the major adjunct. It is not, it is simply an important and contributing adjunct, but the essential element at stake is the greater production of electric power, and its application to the railroads and industries and expansion of inter-connection will continue, until the primaries of today shall become the secondaries of tomorrow. That is the whole thought.

$300,000,000 is a large sum to waste annually. The time will come when you, as engineers, have to stand up and consider the proposition from a national point of view. It is not a question of whether we are going to hurt the private interests—I am not advocating any such thing. I want to preserve them and let them continue in the marvelous developments which they have made in producing such efficient power as they have done,—but I want that activity extended and enlarged and I do not think that the Americanism of the near future will halt this movement. The need for these things is pressing upon us most constantly.

I have talked recently with some of the most important central station men in this country and I have not met anyone as yet who does not realize, as a good American, that this proposition is coming, that it is going through, and they are going to help it.

The question of private interests handling the matter of finances is another problem. If there are $300,000,000 going to waste, and there is a return of 24 per cent by eliminating this waste, the problem will be financed. It may be financed by the private interests themselves, or it may be financed by the private interests guaranteed by the States or the Federal Government or both, but it will be financed. Away back, before we had a nation, the government guaranteed the bonds to lay the rails that were necessary for our trans-continental lines that the country might be developed, and, if it is necessary, the government will guarantee the bonds on this construction, in order that the conservation of our natural resources may be made secure. With these few remarks I would like to present to you Mr. Philip Torchio, Chief Electrical Engineer, N. Y. Edison Co.

Philip Torchio: One of the main features that every speaker has emphasized is the question of the saving of coal by railroads. In that connection I would say that our Chairman was one of the foremost leaders in calling attention to the conservation of coal by electrification, and to the proper way of electrification by supplying the railroads with power from central stations. Mr. Murray for the Railroad and I for the Powers Companies had the pleasure of negotiating one important contract and writing some contributions for the Franklin Institute about six years ago. Since then no railroad electrification has been carried out in this country that has not used central station power.

Now, I want to just briefly touch the high spots in this discussion. These papers are presented not so much from the engineering standpoint, but more from the engineer-citizen standpoint. We as engineers must review the facts from an unbiased standpoint, both for the United States as a whole and for the territory that Mr. Murray is considering. The notes in my contribution embody some views that I gathered from long experience in power matters and power plant operation. These notes are several years old and cover all the United States, but the conclusions arrived at in that case apply also to the case under discussion today.

The first question to determine is, where is the power for this nation to come from? Briefly, in the western states, water power is the logical line of development, because they have immense resources that can supply at the present time six times the requirements for "power and heat" in that territory. Therefore, water power developments in the western states must be considered as basic and pushed forward with all possible energy.

In the eastern states, east of the Rocky Mountains, if you will look at the table that I have prepared a few years ago, and which was based on the use of coal and power in the year 1915, you will see in the column "Total energy (in millions b. t. u.)" that the aggregate use for primary power, and for heating showed a total of 3,786,000,000 units. You will also find in the same column that all the water powers available in all these states amount to 300,000,000 units, or 8 per cent of the total heat units used in 1915. This shows that this country must, forever, as far as we can foresee, use coal as a source of energy.

If that is the case, we have to study to what extent we can use the water power to save coal. If all available water powers had been utilized, they would have represented something like two-thirds of the power used in 1915. I suppose that of the power used in 1919 they would represent about 45 per cent. Prof. Scott has said that we are doubling the power requirements every five years so that it will be only a few years when even with all the water power developed, we shall need to generate from coal the much greater portion of our power requirements.

If such is the case, it follows that we must develop the steam plant and the facilities in connection therewith. The previous speakers have borne testimony to the great progress made by central stations in this country in the last fifteen years; we must advance their progress still further and give them all the aid possible.

There is no doubt but the central stations today are the only coal conservators of the country. After all is said and done, the power engineer of the central station company, who goes next door and shuts down a plant that uses three times the coal the central station plant uses for the development of the same amount of energy, is a conservator of the nation; the manufacturer's motor salesman—the consulting engineer who brings about electrification in any form is a conservator of the country.

There are questions of detail as how to electrify. Should the station be at the seaboard or at the coal mine, and the power distributed over long distances. That may be a disputed question. Mr. Thomas took the view of getting nearer the coal mines. I feel a preference for having the power plant located nearer the large centers of consumption. I am perhaps a little too conservative. I feel, unless there is a very great advantage to be gained, that we should not jeopardize too much the insurance of the continuity of service.

At any rate I want to make the point that if we electrify the railroads, and bring about this interrelation of the production and distribution of power as is described in this paper presented by Mr. Murray, that we can realize the same saving, whether we place

the power plant at the water front near the large centers, or at the mouth of the coal mines, or any other place.

In fact I have demonstrated, in this Table I, assuming we could electrify all the nation, that we would save two-thirds of the coal used for producing power, so that the railroads would have to carry only one-third; the difficulties of transportation would then be very much simplified, and that one-third of the coal still to be carried, would represent perhaps only twenty-five per cent of all the coal carried, including the coal for heat which the railroads must carry in any case.

I made the point that the central stations are the logical vehicles of developing this plan. We ought to continue to do what we have done in the past, increase the interconnections, that is, tie connections between the large centers of generation and distribution.

Incidentally, if Mr. Thomas will allow me, I would rather use a little lower voltage, because if I have to go from here to Albany, and have to pick up a lot of small loads at Poughkeepsie and other places, I would rather handle a sub-station of 110,000 volts or 150,000 volts, than 275,000 volts. It would cost considerable less and be safer.

The potential savings are there. We can realize them in one way or another. The engineering problem is only a question of detail.

One prominent feature referred to in my paper is the question of utilization of water powers. We are very poor in water power, in the east except at Niagara Falls and on the St. Lawrence River, where enormous amounts of power could be utilized. I make a plea that this country should dedicate its water powers to the development of such industries as need continuous power for 365 days in the year, and continuously 24 hours a day, because we can not produce certain electro-chemical and electrometallurgical products, unless such cheap power is available. The utilization of water powers with irregular flows must be only in cooperation with large steam plants. It must be as an annex to a steam plant system.

The question of the utilization of continuous water powers, is one thought that ought to be given considerable consideration, by the national and state officials, they should visualize what are the real advantages to the nation. The relative values of water power and steam power which I have given in the paper may be of some value to anybody who desires to evaluate these conclusions in terms of dollars and cents.

W. S. Murray: W. B. Potter, just before he left last night for Schenectady, on account of an appointment he could not avoid, expressed his regrets to me for not being present today, and he advised me that Mr. Dodd would be on hand to represent him. In connection with the traction field we would like to hear from Mr. Dodd, and if he will honor us with a few remarks, we will very much appreciate it.

S. T. Dodd: In the first place, let me call your attention to an apparent discrepancy between the title of our contribution and the subject as it has actually worked itself out. Mr. Murray asked us to present a contribution on "Heavy Traction Locomotives." When we began to consider the question of type of locomotives which should be recommended and discussed for this proposition, it appeared to us that there was a great deal broader question underlying the whole thing than the question of detail of design of locomotives, and that was the question as to what was the field for these locomotives. You will find that our contribution touches slightly on the question of design of locomotives, but discusses rather fully the field which is open for heavy electric traction; but possibly our contribution fits in better with Mr. Murray's ideas than if we had confined ourselves to the actual subject given in the title.

In looking over the field to be covered, we find the majority of electrifications in the United States are included in the super-power zone. We have presented in our tables the statistics of some nine steam railroad electrifications included in this zone. We find that in the zone there are 380 miles of electrified route, some 1500 miles of track, 230 electric locomotives, and roughly, about 1000 motor cars doing heavy suburban service, so the problem presented is simply the problem of extending to a larger field the same type of traction and the same type of locomotives that have already shown such splendid results.

The first question is, what is the extent of that field. To get some data on that we have taken the official reports of the various roads which traverse the section in question, and tabulated the mileage of the several divisions, thus determining the percentage of the mileage included in the zone. We have applied that percentage to the number of locomotives in service, the ton miles moved, the amount of coal consumed, and it gives us approximately the total railroad traffic which would be included in this zone. Our Table II shows there are 12,000 miles of railroad route; 30,000 miles of single track; somewhere about 8000 locomotives working in the zone at the present time; that the locomotives run about 185,000,000 locomotive miles; they are hauling about 170,000,000,000 ton miles annually and consume about 21,000,000 tons of coal.

In getting at that question of ton miles, we have taken the gross ton miles of freight, the passenger car miles, the locomotive miles, each multiplied by proper factors, to reduce them to ton miles. We have added a certain percentage to cover the amount of switching service, and we finally come to this total of 170,000,000,000 ton miles.

The next question is, if the railroads were electrified what would be the amount of power required to move the same traffic electrically? We have checked that up in two ways. We find that something like 6,000,000,000 kw-hr. per year would be required. This is an outside figure, and will be reduced, when we cut out the amount of coal which would be saved for industrial service; but as an outside figure we can say that it is 6,000,000,000 kw-hr. per year, or an average of about 750,000 kw.

So our conclusions are, something like 750,000 kw. would be required to move the railroad traffic in this section, that there would be a saving of about 14,000,000 tons of coal per year, and there would be still further indicated a saving in maintenance which we have guessed at $15,000,000 per year. We have simply tried to give a broad general view of what the railroad problem is in the super-power zone, and to show that the problem is simply a question of the extension of the same type of railroad electrification and the same methods which are used in other electrifications throughout the country.

W. S. Murray: We have enjoyed hearing from Mr. Dodd, particularly with regard to the matter of coal consumption. I think it is interesting to note that the figures which I arrived at, showed 12,000,000 tons, Mr. Torchio arrived at 13,000,000 tons and Mr. Potter and Mr. Dodd at 14,000,000 tons. That looks like pretty close checking.

One of the things we have not touched upon and for which I blame myself a great deal is in not having a contribution upon the matter of industrial power. I would like to ask Mr. D. B. Rushmore, whom we all know for his interest in industrial power matters, to discuss the industrial power situation it this zone.

D. B. Rushmore: I would like to say that all discussion should end in action, and I would like to see some action taken on this proposition, if agreeable to Mr. Murray—I would like to see this meeting pass some kind of a resolution or suggestion, suggesting that the Board of Directors of the Institute appoint a committee, and I need not say who would naturally be the head of the committee, to take such action as behooves the Institute in following up this work, so that it can be investigated and discussed and rounded up; and I do not think any of us need to assure Mr. Murray of the cordial and hearty support he will receive from all the members of the Institute in carrying on this work, which, if he does aim at the solution he has presented today, must help to solve the problem that has got to be solved.

W. S. Murray: I cannot express to you how deeply your words of encouragment have affected me. I will relinquish the chair in favor of Mr. Rushmore, so that the meeting may take such action in regard to the matter suggested as he and you may deem expedient. I will ask Mr. Rushmore to take the chair.

(Mr. David B. Rushmore in the Chair).

D. B. Rushmore: Gentlemen, we have had a wonderfully interesting discussion, we have had a discussion on a subject looking into the future, a subject of real fundamental and practical importance, no idle dream—it is a problem that is going to be and must be solved. While we may ask the government to take a part in it, and certainly the government, representing ourselves, ought to do its part, the fundamental principles of the engineer's life is to do things for himself, and I think Mr. Murray, who has brought the subject before us, has done a really very valuable service. As many men have said, there always comes a time when the period for discussion ends, and the period for action begins. I should like very much to entertain a motion, looking to some definite action to be taken as the result of the discussion we have had.

H. W. Buck: Following out the most excellent suggestion regarding the appointment of a committee, Mr. Chairman, I would like to offer the following:

Moved: That it is the sense of this meeting to recommend to the Board of Directors of this Institute to appoint a Committee, of which Mr. Murray shall be Chairman, to carry along this most excellent movement which he has initiated today.

(The motion was duly seconded and unanimously carried).

(Mr. W. S. Murray in the Chair).

Mr. Peaslee: I will take a very few minutes of your time to give you an addition to this small contribution I was privileged to make to Mr. Murray's paper, and to say that the results of our research since the presentation of this contribution to Mr. Murray, in the case that our conclusions are not based upon optimism, but upon accomplished fact, and we are ready to undertake to do the installation of the transmission line at any voltage up to 250 kv., if you care to build such a transmission line, and we can undertake to guarantee the insulation of it with a perfectly tried unit that we are willing to go behind. We have so much confidence in it, that our directors have just authorized me to treble the capacity of our plant to take care of the manufacture of such insulators.

W. S. Murray: I want to take this opportunity of thanking you on behalf of myself and for our able contributors for the splendid and encouraging meeting which we have had. I also appreciate the importance of the action which you have just taken.

I said that after the authors had presented their contributions, we would have discussions from the floor. There is one gentleman who is with us who is entitled to our highest respect as one of the greatest central station operators in this country, Mr. Lieb. If Mr. Lieb can honor us with a few words concerning this project, we would be glad to hear from him.

John W. Lieb: I have not any prepared discussion but like all engineers, I am intensely interested in the problems that have been presented here today. The Institute and the nation owe a debt of gratitude to Mr. Murray for having organized this symposium and for having communicated his enthusiasm to the authors of the contributions which have been read, stimulating a wide national outlook on one of the most important economic problems of the day.

It is fortunate, that such a movement has been initiated just at this time, and it should have behind it the momentum and the energy that can be supplied by this body. We should not duplicate the mistake that was made when railroad electrification was first discussed, spending several years in the "battle of the systems" which alarmed the financial interests and made them hesitate to proceed with the work of electrification for fear they might make a fundamental mistake by choosing the wrong system.

Every day that the consummation of such a plan as presented in this symposium is delayed, makes its execution more and more difficult.

It is not merely a question of what the central stations might be prepared to do, and the cooperative spirit they might manifest. It is a question also of the public and the consumers. To effect this tying in of regional systems, many of them might have to change their voltage or the frequency of distribution.

I would like to refer to an experience under war time conditions which has greatly emphasized the need of a nationwide point of view in laying out a plan of this kind. During the war difficulty was experienced in meeting enormous demands for power, far exceeding the available sources of supply, in one district, while at the same time there was a large excess of power in an immediately adjoining district.

Study of the problem showed that what was needed in New Jersey for instance and needed urgently for ship-building plants and extensive war industries, was 60-cycle current. Unfortunately, the service standard obtaining in New York was 62.5 cycles. It was purely accidental that New York, in common with some other localities happened to have a frequency of 62.5 cycles.

The result was that the large surplus of energy unutilized in New York could not be made immediately available in New Jersey. A few days before the armistice was signed, a contract was ready for execution between The New York Edison Company, and The Navy Department to make available 25,000 kw. in New Jersey, but in order to do that, arrangements had to be made to generate that current independently of the general system using 62.5 cycles, so that 60-cycle current might be sent across the river into Jersey.

This matter has been taken up recently, and having

in mind possible future developments and the importance of linking-in and tying-in with adjoining regional systems on the Atlantic Seaboard the New York systems have been standardized on the 60-cycle basis. I want to emphasize the desirability of not postponing action of this kind because every day of delay enormously increases the expense of making such a change. Every day sees the installation of new apparatus on the customer's premises, and where it becomes necessary to make changes in this equipment it may be very costly and serious questions arise as to who should bear the expense of the transformation.

I would like to place proper emphasis on the necessity that arises in great communities like New York, Chicago, Boston, Philadelphia, etc., of being assured, not of relative continuity of service, but of absolute continuity of service, as far as money and human foresight intelligently applied, on a sound engineering basis, can provide. We must provide for the protection of the lighting and power service against all hazards, in view of the importance to the community of maintaining its street lighting, telephone and telegraph service, energy for the high pressure fire pumps, the lighting of firehouses, the fire alarm telegraph system, police stations and many other services absolutely essential to the life of a great center of population.

I think that the time has come, and Mr. Murray with broad vision and foresight has sensed the psychological moment, when this plan of intercommunication of regional power systems should be taken hold of as a broad national problem of supreme importance. The Institute owes a debt of gratitude to Mr. Murray and the authors of these contributions who have so admirably, so effectively, brought this matter forward. We engineers should stand behind it and emphasize its importance to our economists and to our legislators—they depend on us to present the problem and demonstrate its economic importance,—so that the public may have the advantage of the carrying out and development of this great economic policy.

W. S. Murray: The discussion is open to any who may desire to contribute. I would say to you that it is now twenty minutes after one, and I will stay here until midnight, if necessary. If anyone desires to make any remarks, the floor is open, and if anybody desires to leave, no one will feel badly about it.

There apparently being no further discussion, I declare the meeting adjourned.

F. M. Farwell (by letter): I have read with very great interest the symposium on the Super Power System conducted by Mr. W. S. Murray in the JOURNAL for March, and I should like to be permitted to make a few comments on the subject from a somewhat different angle.

Mr. Murray and the other leaders in the profession who joined with him in the symposium have left very little doubt as to the desirability or the feasibility of a super power system such as that presented in the symposium. The idea of such a system seems to have been on the mind of the engineering profession for several months. The able manner in which the matter has been presented by Mr. Murray will add to that interest and should bring about a thorough discussion of all points. The scheme does not seem to offer serious difficulties in either the generating units or the line; but the link which ties the two together seems to have received very little attention thus far.

The switching of large blocks of power, such as are at this time found in some of the larger power systems is quite a serious matter. On such systems short circuits become exceedingly destructive unless oil switches of high rupturing capacity are used. It is customary in large power stations to make all of the principal oil switches of high rupturing capacity so as to take care of a short circuit on any part of the system. In some cases, however, a selective switching scheme is used so arranged that when a short circuit occurs the smaller switches are held closed, forcing another switch of high rupturing capacity to open the short circuit. By this means the number of oil switches of high rupturing capacity may be cut to the minimum.

In the growing tendency toward interconnection, the matter of the increased synchronous generating capacity tied together and its effect on the rupturing of short circuits has sometimes been given too little consideration until the occurrence of a severe short circuit has called attention to it in a manner both forcible and disconcerting. The generating capacity tied into the proposed super power system would be enormous and all this capacity feeding into a short circuit on the system would necessitate dealing with forces of very great magnitude. In case present power stations and distribution systems were connected to the proposed super power system, it is likely that most of the switching equipment in these present systems would be utterly inadequate for the opening of a short circuit with such enormous generating capacity behind it. This would probably involve extensive changes in the switching equipment.

The problem of switching these enormous quantities of power can, I believe, be taken care of in various ways. One way would be to provide the oil switches of the local system with lockout relays so arranged that these oil switches would remain closed on a short circuit until the super power line was disconnected, then let the local switches open the short circuit. Another plan would be the use of a system of selective relays arranged to open the switches in sequence, separating various buses and lines connected in parallel in order to increase the reactance in series with the short circuit and to localize the short circuit and finally select a switch having adequate rupturing capacity to open it. A third method would be to use a system of high reactances which are normally out of circuit but which in case of short circuit would be automatically inserted into the circuit before the oil switch was finally allowed to interrupt the current flowing into the short circuit. It is quite probable that a combination of some of these would be the most satisfactory.

Just how to bring about the accomplishment of such a great project as this super power system is a matter that will bear some further discussion. Three principal elements are interwoven in the scheme, central station power and distribution systems, the railroads, and the common tie lines. As a means of saving coal the electrification of the railroads looms large but except as an additional consumer of power, the railroad part of the project is independent of the electrical system. When assured of a reliable source of supply of electric power the matter of electrification will be entirely a matter for the railroads themselves.

It seems to me that the first part of the scheme to be put through should be the tie line. It is customary for most central stations to have a certain amount of reserve generating capacity in the station to be used in case of breakdown of a generating unit or of

an abnormal load. The interconnection of several stations containing such reserve units will permit of a greater load than before on the group as the safe reserve capacity required will not be so great since it is unlikely that breakdowns would occur in more than one station in the group at a time. The diversity characteristics of the load would also improve the load factor.

The great increase in the cost of labor is going to mean the ever increasing use of machinery to do the work and this naturally means more electric power required. Many industrial establishments are now using central station power; energetic missionary work on the part of the central station companies will add much more industrial load to this. It is possible also that some of the big industrial concerns having their own power systems and utilizing the waste products of the industry such as steel works, for instance, might be induced to tie in with the super power system.

Thus, by pooling all the principal generating stations in the district and reducing to the minimum the idle reserve required for cases of breakdown and overhauling, by the use of the tie line, it is likely that a larger industrial load could be carried than now without increasing the present generating equipment. When the load reached a point such that the generating stations then connected in on the tie line could no longer handle it with safety then the big stations at the coal fields with the high capacity generating units should be built and utilized, retaining the less economical of the present stations as the reserves until such time as it became advisable to abandon them and replace with more modern stations.

It is thus seen that the building of the tie line will first enable the utilizing of the most economical units now in service or being installed in the super power zone and the holding of the least economical units for reserve use in emergency, and second, permit of the handling of considerable additional industrial load without further increase in generating capacity. It would seem to me that much of the money needed to finance the tie line could be furnished by the central station companies by some form of concerted action, using funds that would otherwise be used for extensions to the local stations and funds derived from the additional revenues made possible by local interconnections in anticipation of the building of the main tie line.

AN INDUSTRIAL MOTION PICTURE THEATER

There has recently been put in operation in the Lynn, Mass., works of the General Electric Company a fully equipped motion picture theatre. The auditorium is 130 feet in length and 20 feet wide and will accommodate 390 persons. At one end is a thoroughly modern projection room, in which are installed 4 first-class picture machines of different makes. Screens of various kinds are provided. A permanent screen at the end of the hall is supplied for "movie" shows and a movable screen for experimental purposes can be placed anywhere so as to obtain different lengths of throw and different sizes of pictures. A slot opening is provided in the wall so that this can be removed from the room when it is not in use.

This theater and equipment were installed primarily for the purpose of conducting experiments in connection with the development of the Mazda incandescent lamp and auxiliary equipment for motion picture work, and every facility is provided for obtaining tests on different types of devices, optical systems, etc. Direct-current and alternating-current arcs may be used in comparison with the Mazda equipment. By the aid of the movable screen above referred to any distance of throw up to 130 feet and any size of picture can be obtained so that the conditions encountered in any ordinary theater can be duplicated.

The screen mounted permanently at the end of the room is what is known as the "crystal-bead screen" and consists of a canvas spread with flat white paint in which are embedded a large number of very small glass beads. This provided a very brilliant effect, much brighter than can be obtained with the ordinary type although it is limited to long, narrow halls. The movable screen, on the other hand, is of the ordinary flat white paint variety.

The walls are finished in dull buff and deep browns and a number of life-sized paintings of well-known film artists are hung on the walls.

Although the theater was primarily installed for experimental purposes and is said to be one of the best in the country for this purpose, the facilities are available at any time out of regular working hours, for showing other films for educational and entertainment purposes for any of the organizations connected with the General Electric Company.

The entire outfit has passed inspection by the State authorities, and two of the employes of the department which is handling this development are regularly licensed as motion picture operators. A number of organizations of employes have already taken advantage of this opportunity and interesting meetings are held in this theater noon hours and evenings. As soon as details can be worked out it is expected that employes in each factory will be presented with tickets for certain occasions when they may bring their wives and children. Only the best pictures possible to obtain will be shown and the show will be free to the employes.

The use of the motion picture for educational purposes is only in its infancy, yet there are many films of this character that can be obtained, and with the equipment available there is no reason why many entertainments cannot be given in such places for the instruction and entertainment of employes.—*Safety Engineering.*

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THE WHITE SULPHUR SPRINGS CONVENTION

The 36th Annual Convention of the A. I. E. E. held at the Greenbrier, White Sulphur Springs, June 29 to July 2, proved to be one of the most interesting and enjoyable conventions of recent years. The location was ideal, and the natural beauty of the West Virginia mountains lent added attraction to the abundant facilities provided for all kinds of outdoor recreations. Motoring, horseback riding, swimming and walking over the numerous mountain trails, were freely indulged in by a large number of those in attendance and the golf links and tennis courts were well patronized.

The hotel is well adapted for convention purposes, and the White, in which the technical sessions were held afforded more than usual facilities for the meetings. The meeting rooms were large and well ventilated, opening onto a spacious veranda, and proved comfortable even on the hottest days. The hotel management endeavored in every way to make the meeting a success and greatly aided the convention committee in its efforts to provide for the pleasure and entertainment of all in attendance.

The total attendance of members and guests was 314, including 60 ladies. Twenty-six states and Canada were represented.

The general policy which was adopted in the preparation of the program, of holding the technical sessions in the mornings and leaving all the afternoons and two of the evenings for events arranged by the Convention Committee, consisting principally of contests and other forms of entertainment, including several social events specially provided for the ladies, was favorably commented upon by practically all in attendance, and afforded desirable opportunity for informal discussions, renewal of old associations, and development of acquaintanceship—all of which is now well-known to be among the greatest advantages of gatherings of professional men.

The five technical sessions, held one on each morning and one Thursday evening, were well attended and in spite of a rather crowded program the papers were generally well discussed at considerable length. In order to afford an opportunity to speak for all who wished to discuss the papers, the Meetings and Papers Committee prepared a schedule in advance of the convention, assigning a definite time to which each author and discussor was limited in presenting his remarks. This time limit was adhered to during all the sessions with the result that all who wished to speak could do so. This procedure had the added advantage of improving the discussions which were generally concise and to the point.

The conference of Section delegates, held on Wednesday evening was temporarily adjourned to give the delegates opportunity to attend the piano recital by Prof. Karapetoff, after which the meeting reconvened and discussed questions of Institute policies in which practically every one present took part.

The Board of Directors of the Institute held its regular June meeting on Wednesday afternoon, June 30, as referred to elsewhere in this issue.

The Meetings and Papers Committee held a meeting at luncheon on June 30, for the purpose of formulating plans for future Institute meetings.

Members of several other committees of the Institute held numerous informal conferences during the convention.

TECHNICAL SESSIONS

The first session was opened on Tuesday morning by President Townley who called the meeting to order and after a few words of welcome proceeded to deliver his presidential address on "An Engineering Analysis of the Labor Problem", which is published elsewhere in this issue.

President-elect Berresford was then introduced and spoke briefly acknowledging the honor of his election.

The annual reports of the Technical Committees were then presented. These were discussed by President Townley, William A. Del Mar, H. R. Summerhayes, Selby Haar, Philip Torchio, Dugald C. Jackson B. C. Dennison E. H. Martindale, D. W. Roper, Fred G. Dustin, A. W. Berresford, Ernest V. Pannell, C. A. Copeland, I. Melville Stein, H. L. Hibbard, W. I. Middleton, R. A. Beekman, John Murphy, and Arthur Parker. The members of the committees who presented the reports answered some of the questions raised.

The second session was called to order on Wednesday morning by President Townley. Nine papers were scheduled for this session consisting of two groups classified under the heads of "Electrical Machinery" and "Miscellaneous Papers". All of the papers were read by their authors except Mr. Lamme's paper which was presented by Mr. Newbury.

These papers were discussed by W. J. Foster, F. D. Newbury, R. B. Williamson, Wm. F. Dawson, Robert Treat, Philip Torchio, James Lyman, B. L. Barnes, A. S. Loizeaux, S. R. Bergman, C. J. Fechheimer, S. L. Henderson, C. L. Fortescue, A. E. Kennelly, Joseph Slepian, L. W. Chubb, F. W. Peek, Jr., W. H. Pratt, with closing remarks by the authors. There were also written discussions by R. E. Hellmund and C. W. Kincaid, jointly, and by R. M. Spurck.

Vice-President Wills Maclachlan presided during a part of this session.

The third session was held Thursday morning with Mr. D. W. Roper, Chairman of the Protective Devices Committee presiding. Four papers were presented at this session on the subject of protective devices. Mr. B. G. Jamieson presented the paper for Mr. Schuchardt and Mr. R. E. Doherty presented the paper by Dr. Steinmetz. Mr. F. H. Kierstead and Mr. H. B. Dwight presented their own papers in abstract.

These papers were discussed by A. E. Bauhan, Robert A. Hentz, Dugald C. Jackson, Philip Torchio, James Lyman,

C. J. Holslag, B. G. Jamieson, C. L. Fortescue, R. E. Doherty, V. Karapetoff, Henry R. Woodrow, E. G. Merrick, J. A. Johnson, D. W. Roper, H. R. Summerhayes, J. F. Peters, A. E. Kennelly, H. B. Dwight, A. Nyman, Joseph Slepian and F. H. Kierstead.

The usual closures by the authors were made.

The fourth session was called to order Thursday evening by Vice-President A. M. Schoen, who occupied the chair. There were 19 papers scheduled for presentation at this session, 8 of of which were devoted to Electric Welding and 11 to a symposium on the proper definition of polyphase power factor. It became apparent after the first two papers had been abstracted that the time would not permit of the presentation of all the papers, even in abstract, so by action of the meeting the papers were presented by title only and immediately thrown open for discussion.

The papers were discussed by H. L. Unland, R. W. Owens, A. M. Candy, C. J. Holslag, William O. Noble, William A. Turbayne, Douglas F. Miner, F. V. Magalhaes, F. C. Holtz, V. Karapetoff, C. J. Fechheimer, Robert D. Evans, A. E. Kennelly, Philip Torchio, H. Bristol Dwight, W. H. Pratt, George A. Sawin, J. R. Craighead and C. L. Fortescue.

There was a written discussion by G. G. Post, and closures by several of the authors.

The fifth and last technical session of the convention was held Friday morning, Mr. Philip Torchio, chairman of the Power Stations Committee, presiding. Six papers were presented at this session, all on the general subject of exciter systems for central stations.

After presentation in abstract the papers were discussed by W. F. Sims, E. G. Merrick, William F. Dawson, A. Karapetoff, W. J. Foster, R. E. Doherty, C. J. Fechheimer and James Lyman.

SECTION DELEGATES CONFERENCE

The conference of Section Delegates was held Wednesday evening. Thirty of the Sections of the Institute were represented at the convention by delegates, as provided in the Institute constitution. Following is a complete list of the delegates present:

Section	*Delegate*
Atlanta	A. M. Schoen
Baltimore	J. B. Whitehead
Boston	W. I. Middleton
Chicago	A. F. Riggs
Cleveland	B. W. David
Denver	H. B. Dwight
Detroit-Ann Arbor	G. E. Lewis
Fort Wayne	C. I Hall
Indianapolis-Lafayette	D. C. Pyke
Ithaca	V. Karapetoff
Los Angeles	C. A. Copeland
Lynn	A. K. Warren
Madison	C. M. Jansky
Milwaukee	H. P. Reed
Minnesota	F. G. Dustin
New York	H. A. Pratt
Philadelphia	C. E. Clewell
Pittsburgh	B. C. Dennison
Pittsfield	R. E. Wagner
Portland, Ore.	E. F. Whitney
Providence	R. W. Eaton
St. Louis	G. A. Waters
San Francisco	L. S. Ready
Schenectady	C. S. Van Dyke
Seattle	W. T. Batcheller
Toronto	A. B. Cooper
Spokane	J. E. E. Royer
Urbana	Morgan Brooks
Utah	H. T. Plumb
Washington, D. C.	A. C. Oliphant

The officers present were: President Calvert Townley, New York; Vice-Presidents A. M. Schoen, Atlanta, N. A. Carle, Newark, N. J., Wills Maclachlan, Toronto; Managers Charles S. Ruffner, New York, Charles Robbins, Pittsburgh, E. H. Martindale, Cleveland, Wm. A. Del Mar, New York, W. I. Slichter, New York, F. D. Newbury, Pittsburgh; Secretary F. L. Hutchinson, New York.

Prior to the meeting, all the Sections of the Institute had been communicated with by the Program Committee of the Sections Committee, and requested to suggest subjects for discussion at this conference. Probably because of the fact that the needs of the Sections, as well as the policies of all other Institute activities, had been so thoroughly considered jointly by the Section Delegates and the Development Committee last year and practically all recommendations made at that time had been, or are now being, put into effect, the responses were rather limited; and therefore, the Program Committee arranged for only one meeting of the delegates, to be held on Wednesday evening, thus allowing two full days prior to the meeting for the delegates to meet, become acquainted, and discuss informally before the official conference the various matters in which they were particularly interested.

The subjects thus officially suggested and placed upon the program were as follows:

(1) Geographical divisions as provided in recent constitutional amendment—how many should there be? And how should the limits be defined?

(2) Territorial limits of Sections—should they be modified; and if so how?

(3) Financial support of the Sections from the parent body. Present basis is $100 flat appropriation per section plus $1.25 per member in the Section.

(4) Grades of membership—should there be more or less? And if so what should be the qualifications?

(5) Membership application references. Suggestion has been made that the record of applicant should accompany the forms.

(6) Classification of the field of electrical engineering. *i. e.*, classifying the members of the Institute according to the branches of the industry in which they are specializing, and so indicating this classification in the Year Book.

In the absence of Chairman Walter A. Hall of the Sections Committee, Senior Vice-President A. M. Schoen, of Atlanta, presided at the conference on Wednesday evening and briefly outlined the purpose of the meeting; then introduced President Townley, who, in a brief address, urged upon the delegates present the desirability of free discussion on any matters relating to Institute activities which they deemed of interest. President-elect Berresford then spoke briefly, calling attention to the fact that every recommendation made by the Section Delegates would, as had been the case in the past, receive the careful consideration of the Board of Directors.

Vice-President Schoen then presented for discussion the six topics as outlined above, upon which there was a very general discussion by all the delegates, officers, and others present, after which the meeting was thrown open to other topics. The meeting adjourned at 12:30 a. m.

The entire discussion was reported stenographically and an abstract of all the essential features will be prepared and printed in phamphlet form for distribution to the delegates and the officers of all Sections and of the Institute, and will also be available to any other members who are interested, upon application to the Secretary, at Institute headquarters, New York.

ENTERTAINMENT

The entertainment features of the Convention were especially attractive and were an enjoyable feature of a noteworthy Convention. Much credit is to be given to the capable work of the Convention Committee consisting of Messrs. John H. Finney, Chairman, Walter A. Hall, F. L. Hutchinson, Farley Osgood, Chas. Robbins, A. M. Schoen, and W. I. Slichter, assisted by a part of the "Rebel Brigade" headed by W. S. Lee of Charlotte, W. G. Claytor of Lynchburg, H. G. Scott of Charleston, W. Va., and others. Hotel arrangements were entirely adequate, the hotel management cooperating in every plan proposed for the comfort and entertainment of the Convention members and guests. The guests of the hotel were formally invited to participate in both the technical sessions

and in the entertainment features, and the response was so general that the various events were characterized by large attendance and many pleasant features.

The President's reception Tuesday evening had as a new feature the lady guests of the Convention in the reception line. The formal presentations were made by the Chairman of the Convention Committee and the plan made everybody promptly acquainted with the entire membership in attendance and made the dancing which followed very informal and enjoyable.

On Wednesday evening Professor Vladimir Karapetoff of Cornell University gave an interesting and brilliant piano recital in the Greenbrier Ball Room before a capacity audience. These annual recitals are a fixture of our Convention and always prove a noteworthy attraction.

Base Ball

In spite of the absence of several base ball champions of former conventions, including Farley Osgood and W. A. Hall, and while W. S. Lee was playing a match in golf, the annual base ball game was pulled off according to schedule on Thursday afternoon before a large crowd of enthusiastic rooters. The teams captained by Mr. H. P. Chase and Mr. B. W. David, were composed as follows

	AB	H	R		AB	H	R
Chase, P. H...... 1 b.	6	3	2	David, B. W...... 1 b.	4	2	1
Olsen, M. C...... p.	6	4	3	Townley, C....... 2 b.	4	2	1
Gaskill, J. F...... c.	5	4	3	Norris, F. A...... c.	4	2	1
Doggett, L. S..... 3 b.	5	3	2	Holslag, C. J...... p.	4	1	1
Thomson, G. L. A. l. f.	5	2	2	Kalb, C.......... r. f.	4	3	2
Meyer, A. A...... s. s.	5	3	2	Kyle, G.......... s. s.	4	2	2
Shedd, H. E...... r. f.	5	4	3	Nunamaker, G. S. 3 b.	4	4	4
Croom, C. H...... c. f.	5	4	2	Noyes, M. E...... l. f.	3	1	0
Pollock.......... 2 b.	5	2	2	Hawley, K. A..... c. f.	3	2	1
			—	Helms, H......... l. f.	1	1	0
			21				—
							13

	1st	2d	3d	4th	5th	6th	
David team.............	2	3	4	2	1	1	13
Chase team.............	3	2	0	0	1	15	21

Home Run, Nunamaker 3-base hits, David, Kyle

The afternoon was perfect—many brilliant plays were pulled off—notably the home run of Nunnemaker (who incidentally won thereby the prize for the longest hit)—the daring slide of H. E. Shedd into third—the classy pitching of Olson—the loyal rooting of Mrs. H. P. Chase—were all features of a historic event.

Teas

Teas for the ladies were held on Wednesday in the Spring Room of the Greenbrier, on Thursday afternoon after the ball game at the delightfully situated Kates Mountain Club, and on Friday afternoon in the Casino when prizes were presented. The latter event brought in many of the men and was a fitting windup of the formal Convention events.

Tennis

There were large entry lists for both singles and doubles in tennis, the tournament being very capably handled by Mr. G. A. Sawin of Newark. Men's singles were won by Mr. G. A. Sawin, runner up being Mr. W. Edwards. Men's doubles, finals of which were prevented by rain on Friday, were so far played as to enable a decision to be reached as to winners and prizes were awarded to Sawin and Summerhayes, with C. H. Wolfe and R. D. Evans as runners up.

Golf

Prizes for the various events, under the management of Mr. A. M. Schoen, were awarded as follows:

Low grass score—Mr. A. E. Knight.
Winner 1st 16—Mr. M. G. Kennedy.
Runner up—Mr. W. S. Lee.
Winner 2nd 16—Mr. R. H. Knowlton.
Runner up—Mr. A. C. Cooper.
Winner 3rd flight—Mr. M. McIver.

Mr. Kennedy's victory entitles him to have his name inscribed on the handsome Mershon Golf Trophy, which will become the property of the first person who succeeds in winning the golf tournament at two Institute Conventions. It has previously been won by Mr. A. M. Schoen of Atlanta, Mr. J. C. Mock of Detroit, Mr. E. W. Allen of Chicago, Mr. L. F. Deming of Philadelphia, and Mr. A. A. Brown of New York City.

Ladies Putting Contest

First—Mrs. R. C. Muir, Schenectady.
Second—Mrs. N. M. Garland, New York City.

Bridge Tournament

First—Mrs. W. S. Lee of Charlotte.
Second—Mrs. C. D. Hembold, Washington.
Consolation—Mrs. V. Karapetoff, Ithaca.

Special bridge prizes were awarded to:
Mrs. M. C. Olson of Schenectady.
Miss F. K. Cooke of New York City.
Mrs. T. F. Barton of Schenectady.
Mrs. A. R. Smith of Schenectady.

Hearts

Winner—Mrs. W. J. Foster.

PACIFIC COAST CONVENTION

Portland, Oregon, July 21-24, 1920

The Pacific Coast Convention of the A. I. E. E. was held at the Multnomah Hotel, Portland, Oregon, July 21 to 24. The registered attendance was 251; the various technical sessions and entertainment features were exceedingly interesting and profitable to all who attended and reflected great credit upon the members responsible for the arrangement, including Mr. E. F. Whitney, Acting Chairman and Mr. W. C. Heston, Secretary of the Portland Section; and the Chairmen of Committees as follows: General Convention Committee, R. M. Boykin, Arrangements Committee, J. E. Yates, Entertainment, R. F. Monges, Program, O. B. Coldwell.

Morning Session—July 21

Vice-President, John B. Fisken of Spokane presided at the opening session on Wednesday morning, July 21. Honorable George L. Baker, Mayor of Portland, extended a welcome on behalf of the City. Secretary Hutchinson made a brief address, at the close of which he stated that Mr. Fisken had agreed to accept an invitation from President-Elect Berresford to become Chairman of the Sections Committee of the Institute for the administrative year beginning August first. The announcement was received with unanimous approval.

Dr. C. E. Magnusson of the University of Washington, and Vice-President Elect of the Institute, then delivered an exceedingly interesting address relating to the memorable discoveries of Volta, Oersted, Ampere, Ohm, Faraday and Arago, underlying the progress that has been made in electrical engineering. He called attention to the fact that it was one hundred years ago to a day; namely, on July 21, 1820 that Oersted announced his remarkable discovery of the relation between the magnet and the electric current.

Mr. F. D. Weber called attention to the law now in force in Oregon, requiring registration of all who practise professional engineering in this state. He stated that until July 1, 1920, engineers possessing certain qualifications who were already practising had the privilege of registering without examination and, since that date all candidates were passed upon by an examining board. Engineers already registered include the following: Civil, 805; Mechanical, 178; Hydraulic, 157; Electrical, 119; Mining, 64; Metallurgical, 50; Structural, 36; Chemical, 14; Logging, 12; Naval, 11 and Fire Prevention, 2.

Technical papers were then presented as follows:

"Factors Controlling The Design and Selection of Suspension Insulators" by W. D. A. Peaslee, Consulting Engineer of the Jeffery-De Witt Insulator Company (presented by Mr. Peaslee).

"Unit Voltage Duties in Long Suspension Insulators" by Prof. Harris J. Ryan and Henry H. Henline of the Leland Stanford University (presented by Prof. Ryan).

Afternoon Session, July 21

The Presiding Officer at this session was Mr. E. F. Whitney Acting Chairman of the Portland Section.

The paper entitled "Electrical Characteristics of the Suspension Insulator at the Higher Voltages" by Mr. F. W. Peek, Consulting Engineer of the General Electric Company, Pittsfield, Massachusetts was presented by Mr. R. F. Monges, Portland.

The discussion on the three papers mentioned above was participated in by Messrs. J. B. Fisken, Spokane, M. T. Crawford, Seattle, E. R. Stauffacher, Los Angeles, L. C. Williams, San Francisco, G. E. Quinan, Seattle, W. A. Hillebrand, San Francisco, K. A. Hawley, New York, S. C. Lindsay, Seattle, L. Lauridsen, Portland, A. C. Pratt, Butte, C. P. Osborne, Portland, D. W. Proebstel, Portland, J. C. Clark, San Francisco, H. H. Schoolfield, Portland.

Morning Session, July 22

Mr. R. F. Hayward of Vancouver, B. C. presided at this Session and the following papers were presented by the authors:

"Electric Power Consumption on the Electrified Rocky Mountains and Missoula Divisions of the C. M. & St. P. Railway," by Mr. R. Beeuwkes, Electrical Engineer of the C. M. & St. P. Ry.

Discussion followed by Messrs. J. B. Fisken, Spokane, A. A. Miller, Seattle, G. E. Quinan, Seattle, Paul Lebenbaum, Portland, H. T. Plumb, Salt Lake City, S. C. Lindsay, Seattle, W. J. Davis, Jr., San Francisco, H. J. Ryan, Leland Stanford Univ., E. R. Cunningham, Portland, J. C. Clark, San Francisco, J. R. Read, Vancouver, B. C., R. M. Boykin, Portland.

"Bridge Methods For Alternating Current Measurements" by D. I. Cone, Pacific Telephone & Telegraph Company, San Francisco.

Discussion followed by Messrs: W. A. Hillebrand and R. W. Mastick of San Francisco; H. J. Ryan and J. C. Clark of Leland Stanford University; W. D. Scott and C. E. Magnusson of Seattle; H. V. Carpenter of Pullman.

Afternoon Session, July 22

Mr. G. E. Quinan, Chairman of the Seattle Section presided. A paper entitled "Sawmill Refuse, Powdered Coal and Oil Fuels" by Darrah Corbet of Chas. C. Moore & Company, Seattle, was presented by the author.

Discussion followed by Messrs.: L. T. Merwin, C. P. Osborn, J. H. Paulhemus, H. H. Schoolfield, of Portland; J. B. Fisken of Spokane, S. H. Graf of Corvallis, R. F. Howard, Vancouver, B. C., S. C. Lindsay and Ralph Galt, Seattle and W. A. Hillebrand of San Francisco.

Evening Session, July 22

Doctor C. E. Magnusson of Seattle, Vice President-Elect presided. A paper on "Application of Mild and Alloy Steels to High-Tension Suspension Lines" by L. R. O'Neill, Chief Engineer, Maryland Pressed Steel Company, Hagerstown, Md., was presented by Mr. W. D. A. Peaslee.

Discussion followed by Messrs. John B. Fisken of Spokane, R. W. Sorensen of Pasadena and S. C. Lindsay of Seattle.

INSTITUTE AFFAIRS

A general discussion on the subject of Institute welfare had been scheduled by the Convention Committee for this session. Secretary Hutchinson opned the discussion with a statement rgarding the present status of the principal activities of the Institute, including the actions that have already been taken relative to carrying out the recommendations made last year by the Development Committee and the Sections Delegates at the Lake Placid Convention in June, 1919.

An interesting discussion followed which was participated in by Messrs. L. T. Merwin, J. B. Fisken, C. E. Magnussen, G. E. Quinan, W. A. Hillebrand, R. W. Sorensen, J. C. Clark, H. T. Plumb, H. V. Carpenter, R. F. Hayward, W. A. Scott, H. H. Schoolfield and F. L. Hutchinson.

The session closed by the unanimous adoption of a resolution requesting the Board of Directors to give serious consideration to holding the 1921 Annual Convention in conjunction with the Pacific Coast Convention at Salt Lake City, Utah.

Friday Morning, July 23

Vice President, John B. Fisken presided. A paper entitled "Power Factor Correction of Distribution Systems" by D. M. Jones, General Electric Company, Schenectady, New York, was presented by the author.

Discussion followed by Messrs. J. E. Woodbridge, W. J. Davis, of San Francisco; R. F. Heyard of Vancouver, B. C.; Harris J. Ryan of Stanford Univ.; H. T. Plumb of Salt Lake City; C. A. Whipple of Seattle; O. B. Caldwell and L. T. Merwin of Portland.

The session closed with the unanimous adoption by the visiting members and guests of a resolution expressing their appreciation of the effective services of the officers, committees and members in providing for the comfort and entertainment of all in attendance at the convention.

Entertainment

On Wednesday evening, July 21 the members and guests were taken by the Portland members on an automobile trip over the Boulevards and through some of the beautiful Parks and residential sections of Portland and vicinity.

Thursday, July 22

Thursday afternoon there was a tea for the ladies at the Waverly Country Club, which was greatly enjoyed by the fifteen ladies present.

Friday, July 23

On Friday afternoon a Golf Tournament for the John B. Fisken cup resulted in a victory for Mr. C. L. Wernicke of Portland, who, thereby, is entitled to retain the cup until the next Pacific Coast Convention.

Friday afternoon was utilized by the majority of those in attendance to participate in a trip by automobile over the far and justly famed Columbia River Highway, after which the entire party, including the golfers, attended a banquet at the Crown Point Chalet on the Highway. About 165 members and guests attended. Mr. Whitney, acting chairman of the Portland Section, presided and Vice-Pres. John B. Fisken presented the golf prizes to Mr. Wernicke winner of the tournament and Mr. Whitney who had the low grass score. A brief address relating to effects of the work of the engineer on the social environment of the Pacific Coast States was given by Mr. W. H. Galvani of Portland. Dancing followed until a late hour when all returned to Portland after a most enjoyable evening and with many expressions of appreciation of the manner in which the officers and committees of the Portland Section had managed this and all other events of the Convention.

Saturday was utilized by many of the visiting members to inspect power plants and other places of engineering interest.

A. I. E. E. DIRECTORS MEETING

JUNE 30, 1920

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at The Greenbrier, White Sulphur Springs, W. Va., Wednesday, June 30, 1920, at 5:00 p.m.

There were present: President Calvert Townley, New York; Vice-Presidents N. A. Carle, Newark, N. J., Wills Maclachlan, Toronto; Managers W. A. Del Mar, C. S. Ruffner, W. I. Slichter, New York, E. H. Martindale, Cleveland, F. D. Newbury, Pittsburgh;Secretary F. L. Hutchinson, New York. Also President-elect Berresford, by invitation.

Upon recommendation of the Finance Committee monthly bills amounting to $17,372.94 were approved.

Chairman Slichter of the Meetings and Papers Committee reported that a special committee consisting of himself as chairman and Messrs. Charles E. Bonine, Carl Hering, F. B. Jewett, C. E. Skinner, and W. L. Upson, had been appointed to make arrangements for the October meeting in Philadelphia, which is to be devoted largely to addresses commemorating the one-hundredth anniversary of the electrical discoveries of Oersted, Ampere, Arago and Davy.

Reports were presented of meetings held on June 7 and 21, 1920, of the Board of Examiners; and the actions taken on applications at those meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 80 students were ordered enrolled; 449 applicants were elected to the grade of Associate; 21 applicants were elected to the grade of Member; 59 applicants were transferred to the grade of Member; 18 applicants were transferred to the grade of Fellow.

Reports of the various subcommittees of the Industrial and Domestic Power Committee, consisting principally of outlines of plans of these subcommittees for the preparation of monographs relating to applications of electricity in the various industries covered by the subcommittees, were presented; and it was voted to refer these reports to the Publication Committee for consideration of a plan of procedure in publishing these monographs and similar technical information that may be prepared by other committees of the Institute, including the Marine Rules recently formulated by the Marine Committee.

Upon the recommendation of the Sections Committee, a request for authority to organize an Institute Section at Cincinnati, Ohio, was granted.

Dr. W. R. Whitney, whose term as one of the three representatives of the A. I. E. E. on the Engineering Division of the National Research Council expired June 30, 1920, was reappointed for a term of three years ending June 30, 1923.

An invitation from the American Engineering Standards Committee for the Institute to act with the Bureau of Standards as joint sponsors in the formulation of a safety code for lightning protection, was accepted; and it was voted to authorize the President to appoint a committee of two or three members of the Board to confer with the Bureau of Standards regarding the matter, including the question of organization of a Sectional Committee to carry on the work as required by the Rules of Procedure of the A. E. S. Committee.

President Townley reported orally upon the conference held in Washington, June 3-4, 1920, of representatives of more than seventy engineering societies, including the Institute, and which resulted in a recommendation that these societies join a proposed body to be known as "The Federated American Engineering Societies", the governing body of which will be "The American Engineering Council". Mr. Townley outlined the main features of the constitution as adopted at the Washington meeting and as published in the July issue of the Institute JOURNAL. The following resolution was unanimously adopted:

RESOLVED, that it is the sense of the Board that the A. I. E. E. should join the Federated American Engineering Societies, but that as there is a small attendance at this meeting and a new Board will be constituted commencing with the administrative year on August 1, action be deferred until the August meeting of the Board; and that in the meantime the matter be referred by letter to the members of the incoming Board, with a request that they give careful consideration to the matter and be prepared to act at the next meeting.

The Secretary called attention to the constitutional amendments recently adopted providing for the division of the entire membership of the Institute into districts and the election of a vice-president from each district, and recommended that a special committee be appointed. It was voted that the President be authorized to appoint a committee to consider the division of the membership of the Institute into districts in accordance with the constitutional amendments adopted May 21. and to make recommendations to this Board regarding the number of districts that should be established and the territorial limits of each district.

In addition to these actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the JOURNAL under suitable headings.

At the conclusion of the meeting, the Board expressed its appreciation of the faithfulness and marked ability with which President Townley has administered his office during the past year. President Townley responded briefly, thanking the members of the Board for their hearty cooperation during the year and expressing his appreciation of the opportunities which he had enjoyed of being associated with the members of the Board in the work of the Institute during the past year.

NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

For the Sixth National Exposition of Chemical Industries which will be held in Grand Central Palace, New York, September 20 to September 25, inclusive, there are being arranged the biggest symposiums on Chemical Engineering ever carried out in this country. Up to the present four symposiums have been scheduled. One will be on Fuel Economy, one on Materials Handling, one under the general head of Chemical Engineering, and another on Industrial Management. Moving pictures have played a big part in previous chemical expositions but this year there will be a series of films which will far surpass anything before attempted. The majority of these are absolutely new, in fact some are still in the process of making.

With 370 applications for exhibits already booked, the Sixth National Exposition of Chemical Industries will be on a record breaking scale. The exposition has become an institution in the United States and each year finds new displays that further reveal the ingenuity and cleverness of this country's chemists.

There will be a wide range of exhibits this year. The fact that the exposition has been divided into sections has caused greater interest than ever and the Materials Handling Division and the Fuel Economy Division, both of which will be new this year, have attracted many large concerns.

With the majority of the exhibits tending along the lines of progress and economy it is evident that a visit to the exposition will benefit manufacturers and business men. Impressions not gained elsewhere, and valuable in the future will be stowed away, for a glance into the inside of chemistry has been known to bring improved conditions in many industries and manufacturing plants.

ANNUAL MEETING OF TELEPHONE PIONEERS OF AMERICA

The Seventh Annual Meeting of the Telephone Pioneers of America will be held at Montreal, Canada, on September 10th

and 11th, 1920, with headquarters at the Windsor Hotel. The Bell Telephone Company of Canada will provide entertainment for the members and their families on the 11th. For the trip, special accommodations have been arranged from New York and other points, providing for a side trip to Au Sable Chasm on the return, with a steamer trip through Lake George.

THE FEDERATED AMERICAN ENGINEERING SOCIETIES

One of the outstanding features of the Organizing Conference in Washington, June 3-4, 1920 was the enthusiastic interest and cooperation exhibited by the delegates of the local, state and regional engineering organizations. It is not surprising therefore that these organizations should be among the first to apply for membership in the Federated American Engineering Societies. In this connection it is interesting to note that the Technical Club of Dallas, at its meeting of June 22d made application for membership and at the same time filed its claim as being the first local organization to apply.

At the Annual meeting of the American Institute of Chemical Engineers held in Montreal June 28-29, 1920, the question of the Institute becoming a member of the Federated American Engineering Societies was favorably discussed and referred to the Council for consideration at its meeting on July 25th, at which time definite action will be taken. In the discussion the opinion was expressed that the Institute should be a member of this organization and if its finances would not permit this, that members should be assessed the necessary amount.

The report of the delegates to the Washington Organizing Conference was read at the meeting of the Board of Directors of the American Institute of Electrical Engineers at the Annual Convention at White Sulphur Springs, W. Va., June 30th and the following resolution adopted:

RESOLVED, That it is the sense of this Board that the A. I. E. E. should join The Federated American Engineering Societies, but that as there is a small attendance at this meeting and a new Board will be constituted commencing with the administrative year on August 1, action be deferred until the August meeting of the Board and that a letter be sent the members of the incoming Board, with a request that they give careful consideration to the matter and be prepared to act at the next meeting.

The report of the delegates to the Washington Organizing Conference was read at the meeting of the Board of Direction of the American Institute of Mining and Metallurgical Engineers on June 25, was favorably discussed and referred to the Finance Committee to devise and report on means of meeting the financial requirements.

The report of the delegates to the Washington Conference representing the American Society of Civil Engineers will be presented at the Annual Convention of the Society, at Portland, Oregon, August 10-12, 1920.

In the aftermath of the Washington Conference there has been considerable discussion of the new organization and a number of incorrect statements have been made; one of these is that "During the war, technical men observed the fact that many engineering problems required the joint action of the technical societies. This requirement was met by the formation of Engineering Council. Now the Organizing Conference proposes new organization." This is not correct, as it has been repeatedly pointed out that the work of The Federated American Engineering Societies will be administered by the American Engineering Council which will succeed the present Engineering Council. This procedure received the approval of Engineering Council at its meeting on October 16, 1919, when it endorsed the "General plan for a national engineering council as outlined by the Joint Conference Committee of the Founder Societies."

It has also been suggested in the technical press that "no specific business is as yet outlined for action by the Council" that "The federated society is so completely nebulous that one cannot commend or condemn it" and it will be sometime before the new organization will begin to function. As a matter of fact the Organizing Conference at the closing session on June 4 adopted the following resolution:

RESOLVED, That it is the sense of this Organizing Conference that the Joint Conference Committee should be entrusted with making provisions for putting the conclusions of this conference into effect and that Engineering Council be requested to carry on its work until the new organization has been established, and by all proper means to further the program of the new organization. The Conference further recommends to the contributing societies that they continue supplying the funds required by Engineering Council until its work is taken over by the new organization.

Engineering Council at its meeting of June 17, 1920 unanimously adopted resolutions complying with this request. The resolutions were published in the July JOURNAL.

The action of Engineering Council in accepting the invitation of the Organizing Conference means that the activities of Engineering Council which are those to be undertaken by The Federated American Engineering Societies, will be continued without interruption until the American Engineering Council is prepared to take up the work.

The statement that this new organization "is completely nebulous" is refuted by the fact that the Organizing Conference in Washington adopted a complete constitution and by-laws to govern the organization which came into active existence when The American Society of Mechanical Engineers applied for membership immediately following their adoption, and at which time assurances were given that the Detroit Engineering Society and the American Institute of Electrical Engineers had taken, or would take, similar action.

To this nucleus must be added the Technical Club of Dallas so that The Federated American Engineering Societies has come into active existence and the first meeting of its governing body will be held probably in November of this year.

The organization is to deal with what are commonly known as welfare or non-technical matters. It is not a social organization; it is not an organization of individual members. As its title indicates, it is a federation of societies with whose autonomy and activities it in no way interferes. It does not create a new technical society but it will succeed the present Engineering Council and will be more comprehensive as to scope and membership.

The Federated American Engineering Societies will not in any sense be a competitor of any existing organization. Its success will depend upon the whole hearted support given by the individual engineers and allied technologists of this country through the respective engineering and allied technical societies with which they are identified. The unanimity of opinion in which there was no dissenting vote, with which the following fundamental resolutions of the Washington Organizing Conference were adopted indicated that the psychological moment had arrived for an organization of this character and this fact assures its success:

RESOLVED, That it is the sense of this Organizing Conference that an organization be created to further the public welfare wherever technical knowledge and engineering experience are involved and to consider and act upon matters of common concern to the engineering and allied technical professions.

RESOLVED, That it is the sense of this conference that the proposed organization should be an organization of societies or affiliations and not of individuals.

SOME EXPLANATIONS BY THE JOINT CONFERENCE COMMITTEE

The object of The Federated American Engineering Societies as declared in its Constitution, and as has been repeatedly stated,

> Shall be to further the public welfare wherever technical knowledge and engineering experience are involved and to consider and act upon matters of common concern to the engineering and allied technical professions.

Notwithstanding this, the statement is repeatedly made that the organization does not deal with the interests of the individual engineer and of the allied technologists. The purpose of the organization is that of service first to the nation, state and community, and second, to the profession which obviously must include the interests of the individual. While it is true that it does not deal with the interests of the engineer and technologist as does a labor union for its member, nevertheless its work will do more ultimately to advance the interests of the individual than a labor union could possibly do, because the advancement of the profession through a greater recognition by the public of the engineer and allied technologist, and the greatly increased solidarity and higher standards of these professions must unquestionably work for their ultimate good.

Not a New Organization

The Joint Conference Committee, among others, has referred to The Federated American Engineering Societies as a "new" organization. This is not strictly correct. While the name is new, the organization will be a successor to the existing Engineering Council, whose work will be amplified and carried on on a much more extended plan as to scope and membership.

How and Why the Name was Selected

There has been considerable comment on the name of the new organization. Probably no detail caused the Committee on Constitution and By-Laws of the Organizing Conference, more serious thought than the question of a suitable name. The purpose was to secure a short title that could readily be used, and many suggested names were rejected for good and sufficient reasons. The Committee decided that the name of the organization should be indicative of its character, based on the fundamental resolution of the Organizing Conference, that it should consist of societies and not of individual members. The words "Association," 'Confederation," "Federation," and others were suggested and considered and all were rejected and finally as a compromise the word "Federated" was unanimously agreed to. In view of the fact that other countries are looking with interest on this movement with the probability that there will be similar organizations formed in those countries, it was felt desirable that some distinctive name should be given the organization in this country, and so the word "American" was inserted. Objection to this was made on the ground that this country is the "United States of America" but the answer was that the soldiers of this country fought in Europe as "The American Expeditionary Forces" and have been internationally so recognized. It was thought undesirable to use so long a name as Engineering and Allied Technical Societies especially in view of the fact that engineering as defined in the preamble of the Constitution is an all inclusive word, and it was, therefore, decided to use only the word "Engineering" in the title. Hence the name "The Federated American Engineering Societies."

It is probable however, that when the organization begins to function it will be referred to rarely as The Federated American Engineering Societies but will be called the American Engineering Council which is the executive body of the organization.

Basis of Representation

There seems to be difficulty in understanding what the basis of representation should be where a state organization exists and where there are also strong local organizations and affiliations. The Constitution provides that a state council or organization, representative of the engineers and allied technologists in the state, can be represented on the American Engineering Council on the basis of all the engineers and allied technologists in the state. If however, there exists a strong local organization or affiliation which elects to have its own representative or representatives on the Council then the state council or organization is entitled to representation on the basis of all the engineers and allied technologists in the state, less the engineers and technologists that are to be represented through their local organization or affiliation. This will not prevent the local organization or affiliation from participating in the work of the state council or organization in the consideration of matters affecting the state only.

No Provision for Dues

The Joint Conference Committee has received several letters inquiring as to the provisions for dues. The Constitution and By-Laws provide for funds contributed by the Member-Societies for the support of The Federated American Engineering Societies. Inasmuch as it would be unreasonable for a small local society to pay as large a contribution as a national society the Constitution provides that the contribution shall be on the basis of the number of members in the organization at the rate of \$1.50 per member for national societies and \$1.00 per member for local, state and regional organizations or affiliations. The individual, therefore, does not directly pay any dues but the Member-Society of which he is a member contributes to the support of The Federated American Engineering Societies on a per capita basis of its membership. It, therefore, follows that any one who is a member of several organizations which hold membership in The Federated American Engineering Societies will be counted in the total membership of each Society as a basis of its contribution.

Organization Not Cumbersome

It has also been stated that "the machinery proposed is somewhat elaborate and appears to be cumbersome and expensive." The Joint Conference Committee can see no basis for this statement. The By-Laws provide that

> Any Society or organization of the engineering or allied technical professions whose chief object is the advancement of the knowledge and practise of engineering or the application of allied sciences and which is not organized for commercial purposes, is eligible for membership.

The Federated American Engineering Societies will function through the American Engineering Council which will meet either annually, or bi-annually, as it will determine. This American Engineering Council will consist of representatives from the Member-Societies on the basis of one representative for from 100 to 1000 members and an additional representative for each additional 1000 members or major fraction thereof. From this body of representatives will be formed an Executive Board of thirty, consisting of six officers and twenty-four other members selected in part fom the national societies and the remainder from the local, state or regional organizations or affiliations. The plan reported by the Committee on Constitution and By-Laws provided that the representation on the Executive Board should be based on the ratio of the total number of members in the national societies to the total number of members in the local, state and regional organizations or affiliations. The Organizing Conference however changed this to the ratio of the number of representatives from the national societies to the number of representatives from the local, state and regional organizations or affiliations, on the American Engineering Council. This Executive Board will meet monthly or as often as may be found to be necessary to properly transact the business of The American Engineering Council. There will be an executive officer who will also be the secretary of these bodies and who will be entrusted with carrying out their instructions.

As a matter of fact, the American Engineering Council thus

created is less cumbersome or unworkable than the present Engineering Council; furthermore it has the distinct advantage of being more democratic and broader in its scope and membership.

Organization Conservatively Financed

As to the statement that the organization is expensive, it is pointed out that on the basis of the present membership of Engineering Council the income from the contributions provided in the Constitution of The Federated American Engineering Societies would be about $75,000. At no time in the history of its existence has the budget of Engineering Council exceeded $50,000. Provision is made, however, that

The Executive Board shall, whenever practicable, provide for the whole or a part of the expense of members of or representatives attending its own meetings and those of the Council.

On the basis of past experience, it is estimated that if the expenses of all the representatives on American Engineering Council and of the members of its Executive Board were paid to each meeting of these bodies, there would be involved an annual expense of about $25,000. The purpose of these expenditures was to secure a full attendance of the representatives of The American Engineering Council and on the Executive Board, especially during the earlier years of the organization. As will be noted in the excerpt from the Constitution the expenses of representatives of the Council and members of the Executive Board will be provided from such funds as may be available. If, in the judgment of the Executive Board, this money should be required for more urgent work the expenses of the representatives and members would not be provided for. It seems to the Joint Conference Committee that it would be highly desirable to have sufficient funds to pay the expenses of this representative body of men who contribute their time for the good of the engineering and allied technical professions. The payment of these expenses is the only part of the organization that can be said to be expensive.

Organization Democratic Not Autocratic

It has also been stated that the form of organization that has been set up is "autocratic, not democratic."

If a democratic organization is taken to mean one in which its constitutents have a voice in its affairs then the Federated American Engineering Societies is truly a democratic organization. Member-Societies of this organization are represented on the American Engineering Council which has full power to control and to direct the activities of the American Engineering Council and of its Executive Board and can determine whether it is necessary for the former to meet annually, bi-annually, or tri-annually, or how frequently the latter shall meet.

The Opportunity

The Joint Conference Committee is unqualifiedly of the opinion that an opportunity has been created for bringing about a solidarity of the engineering and allied technical professions that has never heretofore been available and that the success of the movement will depend on the whole-hearted support of each American engineer and of each technologist, who, if determined that this movement shall succeed, will obviously not bother with the details or the form of organization, in his efforts to secure the end desired.

A NEW FRENCH PUBLICATION

The publication of a new review of wireless telegraphy, entitled *Radioelectricite*, will be of interest to technical men as well as to the general public. *Radioelectricite* has been constituted in France by highest men in science and industry, and for its technical part appeals to the most eminent scholars or men of genius. Information regarding the publication may be addressed to 12, Place de Laborde, Paris, France.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

ABSTRACT OF NEW YORK LAW FOR LICENSING OF PROFESSIONAL ENGINEERS AND LAND SURVEYORS*

Effective May 14, 1920

Present practitioners must obtain licenses within 2 years

ADMINSTRATION: In hands of a board of five licensed engineers appointed by the regents of the University of the State of New York.

APPLICATION FOR CERTIFICATE: Must be made on prescribed form to Regents of the University of the State of New York, Albany, New York.

PROFESSIONAL REQUIREMENTS: Law covers all those practising or offering to practise professional engineering or land surveying.

Experience without Degree. To practise Engineering: 6 or more years of active professional engineering work, one of which shall have been in responsible charge, of a character satisfactory to the board. To practise Land Surveying: 4 or more years of active engagement in land surveying work of a character satisfactory to the board.

*Engineering Council does not guarantee the legal accuracy of this abstract.

Educational Allowance. Each two years of study of engineering in a school of engineering of standing satisfactory to the regents considered equivalent as to one year of active practise.

Society Membership. No provision covering membership in a National Engineering Society.

GENERAL REQUIREMENTS: Citizenship of United States. To practise Engineering: not necessary. To practise Land Surveying: necessary,—or a declaration to become a citizen.

Age. At least 21 years.

Miscellaneous. Must be of good character and repute. To practise Land Surveying, must speak and write the English language.

EXAMINATIONS: If evidence presented in application does not appear to board conclusive or warranting issuance of a certificate, applicant may present further evidence, which may include the result of a required examination.

Nature. Not prescribed.

Frequency. Not prescribed.

FEE: For certificate to practise Engineering or Land Surveying—$25.00

For certificate to practise both Engineering and Land Surveying—$35.00

If issuance of certificate be denied, fee shall be returned.

EXPIRATIONS AND RENEWALS: No provisions.

PUBLIC WORK: Two years after act takes effect, no county, city, town or village, or other political sub-division shall engage in construction or maintenance of any public work involving professional engineering or land surveying for which plans, specifications and estimates have not been made by, and construction and maintenance supervised by, a licensed engineer or land surveyor, provided contemplated expenditure for completed project does not exceed $2000.

SEALS: Each licensee may obtain a seal of design authorized by board, bearing licensee's name and the legend "licensed professional engineer" or "licensed land surveyor". Plans, specifications, plats and reports may be stamped with said seal.

EXEMPTIONS: See also "Reciprocity".

Offering to Practise by non-resident.

Employees of Licensed Practitioners. Employees of licensed engineers or licensed land surveyors, so long as practise does not include responsible charge of design or supervision as principal.

Contractors and Superintendents. Not covered by this law.

Federal, State and Municipal Employees. Employees of state or any political sub-division are exempted from the time act becomes effective only until the then existing term of office expires. Officers or employees of United States entirely exempt.

Corporations or Partnerships may engage in the practise of engineering or land surveying provided person or persons connected with such corporation or partnership in charge of design or supervision which constitutes such practise is or are licensed. Same exemptions as apply to individual apply to corporations and partnerships.

Overlapping Duties. Engineers not prohibited from making land surveys essential to engineering projects.

RECIPROCITY: Non-Resident Practitioner may practise in this state, provided he is legally qualified for such professional service in his own state or country, where the necessary qualifications for which meet the requirements of the board of regents. May be granted a certificate upon payment of the required fee if he holds a like unexpired certificate from another state or territory in the United States in which the requirements for license or registration are of a standard satisfactory to the board.

New Resident. Provided he has filed application for license and has paid required fee, may practise for such reasonable time as the board requires in which to consider and grant or deny application.

REVOCATION OF CERTIFICATE: The regents may revoke a certificate for cause only after a hearing at which the accused has the right to be represented by counsel, to introduce evidence and to examine and cross-examine witnesses.

PENALTIES: Any person who, after this act has been in effect 2 years, is not legally authorized to practise and shall so practise or otherwise violate its terms shall be deemed guilty of a misdemeanor and shall for each offense of which he is convicted be punished by a fine of not less than $100 nor more than $500, or by imprisonment for 3 months or both by fine and imprisonment.

LEGISLATIVE INFORMATION: Law is Article IV-A of Chapter 25, Laws of 1909.

Approved May 14, 1920. Introduced into Senate, No. 1104, by Mr. Ferris, March 17, 1920.

Article VII-A, Chapter 25, Laws of 1909 applies to registration of architects. Laws of 1915, Chapter 454.

PAYMENT FOR ESTIMATING

October, 1919, the American Institute of Architects, Engineering Council and Associated General Contractors of America, appointed three conferees each, to discuss the matter of payment for estimating. These conferees agreed upon a report which was submitted to their respective organizations under date of February 17, 1920, and has since been under consideration by them. Engineering Council at its meeting June 17 adopted the conclusion in a report of a special committee to which the report of the conferees had been referred as follows:

Whenever in the execution of work, competitive bids are asked for on detailed plans and specifications, those invited to bid should be provided with such an estimate of the quantities involved in the work as the surveys, plans and specifications permit to be made. The intent of this requirement is that a single estimate of quantities should be made by or for the engineer, architect, or other representative of the owner, so that each separate bidder will not be put to the expense of making up a separate schedule of estimates. This latter practise not only means a needless waste in the carrying on of contract work, but also discourages bidders and causes needless repeated handling of official plans and specifications in making up separate schedules of estimates.

ENGINEERING FOUNDATION

AN AMERICAN HYDRAULIC LABORATORY

Certain engineers have recently proposed an endowed American Hydraulic Laboratory. There are many needed contributions to hydraulic engineering and the underlying science which can best be made by a laboratory with sufficient resources. Numerous problems relating to power development, water supply, irrigation, sewerage, river improvement and other practical applications of hydraulics await solution by the work of competent experimenters in such a laboratory.

In Engineering Foundation there exists the instrumentality for bringing into existence such a laboratory as is suggested. To the limit of its small resources Engineering Foundation during the past year supported Mr. Clemens Herschel in experiments on weirs, which resulted in an improved form of weir and a simple straight line formula. Engineering Foundation Board is thoroughly competent to receive and administer endowment funds in any amount, including those which might be especially designated for an American Hydraulic Laboratory. Furthermore, the Foundation could undertake the establishment and management of such a laboratory and could publish, through the journals of its supporting societies, the technical press and its own bulletins, the results of the experimental work.

Instead of creating a new laboratory it might be found advisable for Engineering Foundation, if funds should be provided, to serve as an American Hydraulic Institute. The Institute could enlarge the usefulness of the existing hydraulic laboratories of the universities, the Government and the industries by directing experimenters and allocating problems to the laboratory best equipped for each specific project undertaken. It could contribute to the support of the experimenter and, if existing facilities were not adequate, could improve the facilities in the laboratory selected for the work.

As the instrumentality of its Founder Societies, Engineering Foundation is ready in this respect to serve the Profession and the industries connected with hydraulic engineering, and to apply the generous gifts of individuals or corporations to the needs of the Profession and these industries.

INTERSTATE COMMERCE COMMISSION NEEDS ENGINEERS

The United States Civil Service Commission states that the Interstate Commerce Commission is making every effort to expedite the valuation of common carriers. The importance of hurrying this work is evident, in view of the law which provided for the return of transportation properties to private

control and which specifies that the Interstate Commerce Commission shall adjust rates so as to insure a fair return upon the aggregate value of the railway property of carriers, the basis being the valuation made by the Commission.

It is stated that the office technical force of the Commission is now engaged in the computation and assembly of the large amount of data furnished by the field engineers. For this office work the Commission needs architects and engineers (civil, mechanical, electrical, structural, signal, telegraph and telephone). Senior architects and engineers are offered entrance salaries from $2,100 to $2,700 a year; junior engineers, $720 to $1,920; junior architects, $1,320 to $1,920. Rodmen and chainmen at $720 to $1,080 will also be appointed in the field and office forces. Employees are given a daily allowance for subsistence, as well as transportation expenses, when away on official business, and are also allowed the increase of $20 a month granted by Congress. The prospects for promotion are said to be good.

The Civil Service Commission will receive applications for these positions until further notice.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

INSTRUCTOR IN ELECTRICAL ENGINEERING at a university located in Central New York, duties beginning Sept. 15th. Must be an engineering school graduate. Opportunity offered to pursue post-graduate. Apply by letter stating age, education and experience, and enclose small photograph if available. Z-1727.

EQUIPMENT ENGINEERS. Men of intermediate type of technical training. Electrical or mechanical. Preferably electrical. These men will be trained in our work to tackle the problems of machine switching, telephony and equipment of new telephone offices with the latest developments in telephone practise. Location N. Y. City. Z-1730.

RESEARCH ENGINEER. Must have had advanced technical training and should have done responsible electrical research laboratory work. Should be familiar with the recent developments of vacuum tubes and high frequency telephone transmission. Should be capable of developing as an executive. Location N. Y. City. Z-1731.

ELECTRICAL ENGINEER with broad knowledge of power plant engineering and operation, and electric railway equipment, to make technical investigations and reports on industrial projects involving extensive use of electric powers, and on railway electrification problems, for the information of an analytical organization in New York City, interested in valuation of investment securities. Complete, detailed, and chronological statement of education, experience, and other qualifications and statement of salary expected, must accompany application. Z-1691.

ENGINEERS with technical and practical training in mechanical, structural, civil and electrical engineering wanted by progressive industrial concern which operates over a dozen plants with main office in Toledo, Ohio. We are organizing our own power, construction, and maintenance department and offer splendid opportunities to first class men who have had drafting experience, as duties include both office and field work. In reply state education, experience in full, salary desired, and when available. Location Ohio. Z-1668.

COMMERCIAL POWER ENGINEER experienced in analyzing and testing isolated power plants, a good general grounding in cost fundamentals, and some knowledge of power rates. Location New York State. Z-1671.

YOUNG MAN, about 25 years of age, with an appreciation for and not intolerant to engineering problems. Should know something about magnetic apparatus and be particularly strong on the subject of humidity, how to measure and control it. Location New York City. Z-1672.

CHIEF INDUSTRIAL ENGINEER, of broad experience wanted for major position on technical staff of an important analytical organization in New York City. Applicant must be familiar with various branches of engineering, and have ability to pass judgment on the scientific, technical and commercial soundness of industrial and other enterprises whose securities the analytical organization desires to consider in making investment recommendation to its clients. No attention will be paid to communications that do not contain complete, detailed chronological information relative to the education, experience, and other qualifications of the applicant. Men whose ability is worth less than $10,000 a year need not apply. Z-1661.

INSTRUCTOR to handle the correspondence course in Armature Winding. Practical experience in Armature Winding is an essential for the work. Teaching experience is somewhat desirable, but not at all essential. The theoretical part of the work does not enter; there is a slight amount needed. Man who knows the subject of Winding in several different ways, particularly in maintenance work, in general repair shop work and in shop manufacture. Location New York City. Z-1642.

FACTORY MANAGER—POLYPHASE MOTOR MANUFACTURE. Expansion of facilities and rearrangement of duties have left open position of Factory Manager. Satisfactory record of results accomplished must be submitted, including production and indicating a thorough familiarity with economical design and manufacture. This is an excellent opening for a man of the proper qualifications, and first communication should give complete information as to ability, salary expected, etc. Only those of proven ability will be considered. Location Michigan. Z-1620.

INSTRUCTOR to teach either or both electrical and mechanical engineering. Prefer young man with some practical experience or man who desires to come to the Pacific Coast for personal reasons. Location California. Z-1599.

ASSISTANT to engineer in charge of one of the best known electrical laboratories in the country is open to a technical engineer of several years laboratory experience. Principal duties will be to supervise the experimental and development work of the Laboratory. This work is chiefly on electrical measuring devices. Salary commensurate with experience and ability. Location New England. Z-1540.

MANAGER OF SHIPPING AND RECEIVING, to take charge of operations, involving large tonnage in connection with railroad, motor truck and marine shipments in a plant covering extensive acreage. Must be thoroughly experienced and able to take entire charge of organizing planning and carrying out the work efficiently. Plant located one hours ride from New York City. Z-1531.

SUPERINTENDENT OF MINING property in Chile. Technical graduate, preferably in Electrical or Mechanical. Executive and operating experience in electric railroading, steam turbine power plant, and open pit mining desirable. Only experienced men wanted. Knowledge of Spanish desirable, but not necessary. Good opportunity for right man. Give age, married or single. Education, technical training, technical and executive experience, salary expected, references and when available. Location Chile. Z-1355.

INSTRUCTOR IN ELECTRICAL ENGINEERING. Duties beginning September 1st, in New England Engineering College, mainly instruction in electrical engineering Laboratory.

Graduate of one or two years engineering experience desired. Z-1284.

ELECTRICAL AND MECHANICAL ENGINEER for 3000 h. p. hydro electric plant in Bolivia. Must be able to improve efficiency and take charge of plant. Z-1150.

TECHNICAL GRADUATE, with some teaching experience and some experience in the designing and testing of electrical machinery, to take charge of a dynamo laboratory, together with some classroom work, in a day and evening technical school in New York. Salary $2700. for nine months work. Write particulars, regarding age, education and experience. Z-1789.

MEN AVAILABLE

ELECTRICAL ENGINEER, technical graduate, 1916. Three years experience plant department of telephone and telegraph company. Some experience lighting and power layouts also teaching experience. Salary desired depends upon location and opportunity. E-2255.

ELECTRICAL ENGINEER, 8 years practical experience. Telephoning, Power House and Sub Station installation. Inspection. Testing. Age 28, Married. Available September 1st, 1920. E-2256.

ELECTRICAL AND MECHANICAL ENGINEER. Hold second assistant unlimited marine license, but prefer stationary work. Two years technical training. Seven year practical stationary and marine steam and electrical, 1 year office work with well known manufacturer of electrical equipment. Prefer permanent location New York City. E-2257.

ELECTRICAL ENGINEER. 29; married. Technical education; 4 years generating station and substation operation. Past 3 years in engineering offices on the design of stations, transmission, lighting, and industrial motorizing. Available August 1. Salary $2400 per year. E-2258.

MECHANICAL AND ELECTRICAL ENGINEER, age 36. Technical graduate. 13 years experience in design, construction and operation of hydraulic, steam and electrical installations. At present employed in large industrial plant as general superintendent. Experienced in organizing operating forces for new and unusual industries. Salary $6000. E-2259.

EXECUTIVE ASSISTANT to general manager or chief engineer of a manufacturing concern, holding company or public utility. Experience 2 years teaching; three years construction work; three years consulting engineering work for federal and state governments. Can assemble corps of engineers familiar with the Polish, Russian, German and French languages on reasonable notice. Member A. S. M. E. and A. I. E. E. Salary $4500-5000. E-2260.

GRADUATE ELECTRICAL ENGINEER, 6 months Westinghouse test, 2 years central station and sub-station design, 6 months factory illumination and motor control layout, 2 years U. S. Army Officer Motor Transport Corps, 5 years general automobile experience, desires commercial position. Available July 1st to go anywhere. Will consider any good proposition. E-2261.

ELECTRICAL MECHANICAL ENGINEER; practical and technical man open for engagement as superintendent of power, consulting, or developing engineer. Eleven years broad experience in management, maintenance, operation, construction, and installation of power plants and mines. Last three years spent in mining and oil field work. Minimum salary $3600. E-2262.

ENGINEER technically trained, 5 years railroad operating and construction experience. Also several years varied electrical work including 2 years General Electric Test. At present employed in engineering department of large electrical manufacturing concern but desire change to electrified Railroad field. Single, 35, Minimum salary $1800. E-2263.

ELECTRICAL ENGINEER, over 12 years experience in operation, design and construction. Desires position as Superintendent of operation or construction or responsible position in connection with design. Salary $3600 to start. E-2264.

ELECTRICAL ENGINEERING TEACHER, 12 years experience at institutions of recognized standing. Position leading to head of department preferred. Broad experience in commercial engineering work. Age 35, married. Minimum Salary $3500. E-2265.

PRACTICAL ELECTRICAL MAN—age 32, 10 years electrical experience desires position as Instructor of Electrical subjects. Thorough training in electrical work while in the army. Employed at present. Minimum salary $1600. References on request. E-2266.

ELECTRICAL ENGINEER. Want to locate with repair shop or dealer in used electrical machinery in vicinity of New York City. Experience covers armature winding, trouble work, buying and selling. Excellent references. E-2267.

ELECTRICAL ENGINEER, technical graduate, age 28, single. 2½ years Westinghouse test, 2 years United States Navy. 1 year construction work. Some research and production work, good organizer. Wish to locate with a power or industrial firm or with a manufacturer of machinery equipped with electric drive. E-2268.

UNIVERSITY GRADUATE in electrical engineering, single, age 29, eighteen months Westinghouse test, last two years naval officer. Some knowledge of Spanish, German, French and Russian. Desires position on construction work or operating. Will go to South America. E-2269.

TECHNICAL GRADUATE, desires sales or engineering work in or near Los Angeles, Cal., qualifications four years practical electrical work, four years sales experience, in addition to steam engineering training and experience in the navy. Can organize and manage sales agencies, age 31. E-2270.

ELECTRICAL ENGINEER. Technical graduate; age twenty four, single. Two and a half years experience in testing department of Westinghouse Elec. and Mfg. Co. Thoroughly familiar with all steam power plant apparatus, layout and construction. Desires position with consulting engineering firm or firm anticipating extensions in power system. Location west or middle west. Minimum salary $2100. E-2271.

ELECTRICAL ENGINEER, 31, married, ten years broad and intensive experience in large power and industrial plants, covering switchboard design and construction, power plant layout and erecting, shop practise and testing. Past two years with large manufacturing company as Erecting and Repair Engineer. Desire change to position requiring tact, efficiency and thorough knowledge of all phases of electrical construction and operation. Minimum salary $3000. Available on reasonable notice to present employers. E-2272.

PRACTICAL ELECTRICAL ENGINEER, 28, married. Three years technical training, 7 years engineering experience in construction, maintenance, central station work, mine and mill electrification and operation. Salary depends on location. E-2273.

GRADUATE ELECTRICAL ENGINEER, married, 36, twelve years construction and operation various types power plant and mill electrical apparatus. Experienced in large sizes and complex controls. Eight years of above with one of largest electrical manufacturing companies. Desires to locate off the "road". Present salary $3400. E-2274.

SALES REPRESENTATIVE, experienced salesman, with New York office and established clientele in automobile, hardware, electrical trades, solicits an additional account for Metropolitan district on commission basis. E-2276.

ELECTRICAL ENGINEER. Technical graduate, G. E. test-man. Experience in Radio Telegraphy and Telephony. Practical experience in factory production. Industrial manufacturing or Hydroelectric position desired where progress is assured according to ability shown. Position in consulting engineering office would be considered. Location in New England preferred. E-2277.

ELECTRICAL ENGINEER, age 32, married, technical education, 10 years with large electrical manufacturing company, on test floors and as engineer in charge of design of all classes of switching equipments including layout for large power house and substation installations. Energetic and a good organizer. Desire position as executive or as consulting engineer. Available August 1st. Middle West preferred. Salary dependent upon location and opportunities for advancement. E-2278.

SALES ENGINEER, wishes position with a manufacturing company, to act as agent representative or sales manager, for the sale of electrical and mechanical apparatus, familiar with New England territory and foreign trade. Or position with an undustrial organization for the development of above trade conditions. E-2279.

TECHNICAL GRADUATE, experienced in sub-station and high tension transmission design, desire a position where ability and hard work can be capitalized. Age 25, married. Location unimportant. E-2280.

MANAGER ENGINEERING DEPT. of Large New York Export & Import house desires to make a change. A graduate Electrical Engineer having also studied law, 29 years of age, single, with eight years commercial and engineering experience in U. S., Canada and Europe. A successful organizer and executive. Salary $6000. E-2281.

CONSTRUCTING AND OPERATING ENGINEER, executive ability, excellent personality, energetic, aggressive, M. I. T. 1915. Experience with Electric Light and Power Co. Assistant Electrical Engineer, Central Station design and develop-

ment of Operating statistics. At present with firm of Construction Engineers as Assistant Local Electrical Engineer, Design office, 200,000 K. W. Central Station. Responsible for purchasing all electrical material. Salary has increased 93% in ten months. Desire permanent location. Available 30 day notice. Salary $4000. E-2282.

TESTING ENGINEER, with three years electrical laboratory and eleven years public utility and central station experience. Am expert on all branches of electrical instrument and meter repair work. Location preferred New York City or vicinity. Salary $2400. E-2283.

GRADUATE ELECTRICAL ENGINEER, age 26, single, has had experience in telephone work, both automatic and manual; general plant maintenance, and in the design and layout of power houses and substations. Desires something permanent in any locality. E-2284.

ENGINEER, with eleven years practical experience in the Construction and Maintenance of High & Low Tension Transmission and Distribution Systems, Power Generation, Oil, Gas and Steam Engines; a competent executive; at present employed as general Superintendent of Light and Power over eleven towns and two plants. E-2285.

GRADUATE ELECTRIC AND MECHANICAL ENGINEER. Age 30. B. S. and E. E. degree with 10 years experience in the design of sub-station and power plants, also construction, industrial and commercial for light, heat and power. Employed at present with a public service corporation. Salary $2500 to start. Available at once. Location New York vicinity. E-2286.

INSTRUCTOR IN ELECTRICAL ENGINEERING, Electrical Engineer, age 26, degree B. S. 1917, employed in design and supervision of construction of electrical railway equipment, desires teaching position (engineering subjects) in technical school or college. Minimum salary $2200. Location in or near New York. E-2287.

ELECTRICAL ENGINEERING EXECUTIVE, thoroughly versed in modern efficiency methods of factory production, planning, scheduling and costs. Has had nine years experience in the design and manufacture of electrical cables. Good correspondent with knowledge of French and German. Seeks position with future. Minimum salary $4500. per annum. E-2288.

ELECTRICAL ENGINEER for large industrial plant desires immediate change to similar work. Graduate 1909, 33 years married, eleven years experience, covering apprentice, sales, testing, estimating, layout, maintenance and construction work. Salary $3600. E-2289.

ELECTRICAL ENGINEER, five years technical training, five years substation and steam turbo plant operation, five years assistant electrical engineer street lighting maintenance and construction, one year foreman power and lighting installations. Would consider export firm or local offering responsible position and broader opportunities. Salary commensurate with duties and location. E-2290.

GRADUATE ELECTRICAL ENGINEER, age 40, married with eighteen years experience in Mechanical and Electrical Engineering desires a position as Factory Manager, Superintendent, or Production Engineer, in a factory manufacturing electric motors, or other electrical apparatus. Minimum salary $4000. E-2291.

EXPERIENCED ELECTRICAL AND CIVIL ENGINEER with B. S. and M. S. Degrees from large universities, desires professorship of Engineering or headship of department of physics or in the manufacture and sale of scientific and engineering equipment. Has had experience as professor of Physics, electricity, and engineering branches. Also has served as assistant city engineer, highway engineer, and consulting electrical engineer, and one year as factory manager. Salary $6000. Location immaterial. Available short notice. E-2292.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—W. Ammen, 133 Franklin Ave., Mt. Vernon, N. Y.
2.—Edwin G. Helm, Construction Dept., Potomac Ry. & Pr. Co. Martinsburg, West Va.
3.—Carl Irving, 1253 West 51st Place, Los Angeles, Cal.
4.—Cyril H. Light, Office of Inspector of Engg. Material, U. S. N., 938 Edison Bldg., Chicago, Ill.

PERSONAL

CHARLES O. RAUSCHKOLB has been put in charge of a new sales office and service station of the Wagner Electric Manufacturing Company at No. 2007 South Ervay Street, Dallas, Texas.

J. R. WERTH has resigned as Major from the Construction Division of the Army and has opened an office at 6823 Thomas Street, Pittsburgh, for furnishing technical advisory reports to electrical and industrial corporations.

L. L. WILLARD sends announcement that the business heretofore carried on under the name of W. J. Rainey has been incorporated and will be conducted under the name of W. J. Rainey, Inc., at 52 Vanderbilt Avenue, New York City. Mr. Willard is a vice-president of the firm.

IRVING E. MOULTROP, Chairman of the Boston Section of the Institute, was on June 24 elected by the trustees of the United Engineering Society to fill the vacancy on that Board caused by the recent death of E. Gybbon Spilsbury, one of the trustees representing the American Society of Mechanical Engineers.

OBITUARY

LEWIS T. GLASER formerly electrical engineer with the Municipal Electric Light Plant of Cleveland, Ohio, died on June 8, 1920, after a lingering illness. Mr. Glaser started his electrical work in 1910 with the Wenatchee Valley Gas & Electric Company, Washington as a meter tester. In four years he became Assistant Superintendent. He then entered the employ of the Cleveland Municipal plant in charge of underground construction, wiring, switchboards, etc. Mr. Glaser was elected an Associate in the Institute in 1914.

FRANCIS W. THROOP, who was Hydraulic Engineer with the Empresa Electricas Asociados, Lima, Peru, was killed on March 24, 1920 at Chosica near Lima as the result of an accident. Mr. Throop, on a tour of inspection, was riding his horse along the banks of one of the streams feeding the hydroelectric plant. The bank, undermined by the freshets, gave way and rider and horse were lost. Mr. Throop was a graduate of Cornell in the class of 1892. On leaving college he accepted a position with the Bell Telephone Co., later entering the employ of the G. E. Co., the Pittsburgh Reduction Co. and others. In 1908 he became Power House Supt. for the Ft. Hamilton Cataract Power, Light & Traction Company at Hamilton, Ont. In 1918 he entered the employ of the Empresa Electricas Asociados. Mr. Throop was elected to the grade of Associate in the Institute in 1909.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (JULY 1-31 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Direct-Current Motor and Generator Troubles—Operation and Repair.

By Theodore S. Gandy and Elmer C. Schacht. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc.; 1920. 274 pp., illus., tables, 8 x 6 in., cloth, $2.50.

The chief object of this book is to give simple, effective methods for finding and remedying troubles of direct-current motors and generators. In addition, the selection, operation, care and repair of direct-current machinery are analyzed from the operator's point of view. The theory underlying the design of these machines is omitted, as the book is intended for operators, not for designers.

Drainage Engineering.

By Daniel William Murphy. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc., 1920. 178 pp., illus., plates, tables, 9 x 6 in., cloth, $2.50.

This is a general treatise on the drainage of agricultural lands, which indicates the various questions to be considered in connection with a drainage project, and presents the principles involved in the design and construction of drainage works. The author was formerly a Drainage Engineer in the U. S. Reclamation Service.

Engineering for Land Drainage.

A Manual for the Reclamation of Lands Injured by Water. By Charles Gleason Elliott. Third edition, revised, N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1919. 363 pp., illus., maps, tables, 8 x 5 in., cloth, $2.50.

Contents: Development of Land Drainage.—The Drainage Engineer.—Engineering Technique.—Drainage and How Accomplished.—The Preliminary Survey.—Underdrains and their Location.—Flow in Underdrains. The Runoff from Underdrained Areas.—Size of Tile-drains.—Selection of Drain-tile.—Construction of Tile-drains.—Flow in Open Channels.—The Runoff from Large Areas.—Location and Construction of Open Ditches.—Problems in Openditch Work.—Drainage Districts.—Levee Drainage Systems.—Reclamation of Tidal Lands.—Drainage of Irrigated Lands.—Drainage of Peat and Muck Lands.—Control of Hill Waters.—Drainage of Home Surroundings.—Estimates and Accounts.—Records.—Tables.

This book is prepared to present the essential features of drainage engineering as practised in this country today and is adapted to the use of professional engineers and students. This edition has been revised and enlarged. The discussion of the hydraulics of flow has been rewritten and new tables for the discharge of tile drains are given. A diagram to facilitate the use of Kütter's formula in the design of ditches and canals has been added, as well as new material.

Die Helmholtzsche Wirbeltheorie Fur Ingenieure.

By G. Bauer. Munchen & Berlin. R. Oldenbourg, 1920. 146 pp., illus., diagrams, 10 x 7 in., paper, 14 marks.

The hydrodynamic problems met in such fields as airplane and ship building call for an acquaintance with the theory of vortex motion, but this theory, although it has for some time taken a considerable and useful place in electrical theory, is less well known by those engaged in other fields. It is the author's opinion that the chief cause of this ignorance is the lack of any work from which the engineer can obtain an understanding of the theory of vortices with a minimum of effort, a lack that the present monograph is intended to supply.

The method adopted is that of a commentary on Helmholtz's famous paper of 1858 on vortex motion. The paper is presented in full, with extensive illustrations and explanations. Helmholtz's two answers to Bertrand's papers on the motion of fluids are also included.

International Commerce and Reconstruction.

By Elisha M. Friedman. With a foreword by Joseph French Johnson. N. Y., E. P. Dutton & Co., copyright, 1920. 432 pp., tables, 8 x 5 in., $5.

Beneath the military campaigns of the war, a silent economic process has been changing the character of the commerce of the world. Profound changes have taken place, which this book attempts to trace in detail, and the principles of which it aims to discuss. It recites some of the facts essential to the formation of a new commercial and financial view and advocates a definite trade policy for the retention of our commercial gains from the war years.

Inventions. Their Development, Purchase and Sale.

By William E. Baff. N. Y., D. Van Nostrand Co., 1920. 230 pp., 8 x 5 in., cloth, $2.00.

The author of this work discusses the marketing of inventions. The subject is considered from the various points of view of the inventor, the capitalist or investor, and the manufacturer, and advice given to each as to the methods for making a correct judgment of the value of any invention.

Die Magnetische Induktion in Geschlossenen Spulen.

By Arthur Scherbius. Munchen & Berlin, R. Oldenbourg, 1919. 91 pp., illus., 10 x 7 in., paper, 7 marks.

This monograph treats of the possibilities, both theoretical and technical, of phase transformation by transformers and machines without commutators. The author discusses these possibilities with special reference to the limits within which technical applications may be possible and gives particular attention to the saturated transformer.

Manual for the Oil and Gas Industry under the Revenue Act of 1918.

By Ralph Arnold, J. L. Darnell and Others. N. Y., John Wiley & Sons, Inc.; Lond. Chapman & Hall, Ltd., 1920. 190 pp., charts, tables, 9 x 6 in., cloth, $2.50.

This manual was first issued in 1919 as a bulletin by the Oil and Gas Section of the Bureau of Internal Revenue. The demand having exceeded the supply, this private reprint, in which certain features have been brought up to date, is published.

The book is intended to assist the taxpayer of the oil and gas industry in preparing his Federal tax returns correctly and expeditiously. It is divided into three parts. Part one deals directly with the law and regulations, part two with depreciation, while part three describes methods of estimating underground reserves, especially by means of production curves, a collection of which are included.

RESISTANCE DES MATERIAUX ET ELASTICITE.

Cours Professé a l'Ecole des Ponts et Chaussées. By Gaston Pigeaud. Paris, Gauthier-Villars et Cie, 1920. 772 pp., diagrams, 8 x 6 in., paper, 64 francs.

This textbook represents the instruction given at L'Ecole des Ponts et Chaussees, and its arrangement, the author states, has been largely determined by the necessity of quickly preparing the students to apply the subject in the field of girders. At the beginning there is, therefore, no attempt to introduce the study by a preliminary exposition of the theory of elasticity, and throughout there is an avoidance of abstract principles.

After a brief review of the principles of mechanics and graphic statics, the theory of girders is explained. This is followed by a discussion of the various uses of the girder. The theory of elasticity is then introduced and occupies the concluding third of the book.

THE RUDDER MARINE DIRECTORY.

A Trade List of Shipbuilding and Marine Industries. N. Y., Rudder Publishing Co., 1920. 438 pp., 9 x 6 in., cloth, $5.00.

The title of this directory is sufficient indication of its contents, and suggests its possible usefulness to those interested in ship construction and operation. The present edition is considerably larger than the first, which appeared in 1919. The lists are conveniently classified and arranged to facilitate their use.

DIE SCHALTUNGSGRUNDLAGEN DER FERNSPRECHANLAGEN MIT WÄHLERBETRIEB.

By Fritz Lubberger. Munchen & Berlin, R. Oldenbourg, 1920. 168 pp., plates, 13 x 9 in., boards, 28 marks.

This book is intended to give engineers acquainted with manually operated telephone exchanges an introduction to automatic systems, which are frequently so confusing to the beginner. The author has made an extended examination of the systems of wiring used or proposed for this purpose and has selected the essentials of proper procedure from them.

Beginning with an easily understood automatic circuit, the book then proceeds to describe generally the principles of the various parts of the circuit, and follows this with explanations of the various systems that have been devised for the practical solution of the problems involved. The book includes bibliographical references, a list of German patents and many plates illustrating the arrangements described.

SERVICE AT COST PLANS.

An Identical Analysis of Statutes, Ordinances, Agreements and Commission Orders in Effect, or Proposed, together with a Discussion of the Essentials of Local Transportation Franchises. By Harlow C. Clark. N. Y., American Electric Railway Association, 1920. 315 pp., 9 x 6 in., cloth, $2.50.

The existing necessity for a readjustment of the rates for local transportation companies upon a basis that, while it protects the public from excessive charges, will attract the new capital necessary for the development of transportation facilities as extensions are demanded, has led to the introduction of various "service at cost" plans in a number of communities. This volume is intended to provide the public and the operators of local transportation facilities with a convenient summary of the principles and details of the various cost of service plans that have been adopted or proposed. It contains a statement of the principles that must underlie any legal expression of the right to conduct these utilities, if private capital is to be secured, an examination of the various statutes, ordinances and orders to ascertain the extent to which these principles have been applied, and identical analysis of the plans in service and proposed.

ROMANCE OF A GREAT FACTORY

Charles M. Ripley

The Gazette Press, Schnectady, N. Y. 1919.

"Romance of a Great Factory" presents the human interest side of present day industry as typified in a great factory, that of the General Electric Company at Schenectady, New York. While avowing that "with no effort to produce 'literature', these stories were hastily dictated while still under the spell of the spectacular and awe-inspiring scenes witnessed on various trips through our great factory employing nearly twenty-five thousand men", the author suceeds in putting before the reader a vivid and realistic picture of the factory life, with the shop worker and his interests in the foreground, and with a back ground of scientific and statistical information that adds to its value.

Following an introduction by Dr. Charles P. Steinmetz, the author plunges into factory life amid "The Great Industrial Orchestra", as the first chapter is entitled. He finds himself at 12:30 p. m. in building number 49 as the whistle blows to end the dinner period. "In less time than it takes to describe it, lathes, drill presses, cranes and hand tools all joined together singing their respective parts, and I was surrounded by a great industrial orchestra—the building reverberating to the indescribable song of American industry." He then shows the meaning of the song, which in building number 49 is "steel for our ships".

Each chapter is a story in itself, that may be read and enjoyed separately. The style is spontaneous, as the author dictated the work directly to his "Electrical Secretary", an "Ediphone" or Edison business phonograph; "Miss Edison", he explains, was always ready for anything, even taking a trip with him once on one of the ponderous cranes handling freight. Some of the chapters that are of special popular interest are Chapter XI, "The Girls' Part", in which the dexterity of the girls working in the factory is illustrated, and the safety and convenience of their working place are emphasized; and Chapter XII, "The Peace Celebration", which takes one back to November, 1918, to see the factory evacuated in less than an hour when the great steam whistle sounded.

Following the numbered chapters are "Fragments", among which items of interest are given Dr. Steinmetz's private system of shorthand, the average employe's years of service with the company, the number of fatal industrial accidents in the factory, showing that fishing is more dangerous than working in the factory, and the work of the Committee of One Thousand in selling Liberty Bonds, with a list of its members.

The book is profusely illustrated, and will prove of interest to members of factory organizations as well as to uninitiated outsiders.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Baltimore.—April 23, 1920, Engineers Club. Subject: "The Suspension Insulator for High-Voltage Power Transmission—Its Past and Future." Speaker Mr. F. H. Allner, of the Penna Water & Power Co. Attendance 28.

April 26, 1920, Johns Hopkins University. Joint meeting with Baltimore Section A. S. M. E. Subject: "The Super Power System." Speaker: Mr. W. S. Murray. Attendance 98.

May 14, 1920, Johns Hopkins University. Illustrated lecture on "The Safety Car." Speaker: Mr. C. H. Beck, of the Westinghouse Traction Brake Company. Attendance 49.

May 21, 1920, Engineers Club. Subject: "The Future of Hydroelectric Development." Speaker: Mr. W. C. Grover, U. S. Geological Survey.

Cleveland.—May 18, 1920, Rooms of Cleveland Engineering Society. Business meeting and election of officers as follows: Chairman, A. M. MacCutcheon; Secretary-Treasurer, G. M. Cameron; Chairman Papers Committee, Irving Van Horn; Directors, W. D. Smoot, E. S. Connell, H. S. Wallau, B. W. David (ex-officio). Attendance 140.

The business meeting was preceded by a dinner. Mr. P. M. Lincoln acting as master of ceremonies. Talks were given by

Messrs. Bush, MacCutcheon and others, followed by Professor V. Karapetoff, whose subject was "Some Present Day Problems in Electrical Research."

Detroit-Ann Arbor.—June 25, 1920, Detroit Board of Commerce. Annual Meeting and Banquet. Speakers: Messrs. E. S. Elliot, E. H. Martindale and D. V. Williams. Election of officers as follows: Chairman, C. E. Kittredge; Vice-Chairman, A. S. Albright; Secretary-Treasurer, C. E. Wise. Attendance 50.

Pittsburgh.—June 8, 1920, Chamber of Commerce Building. Election of officers as follows: Chairman, B. C. Dennison; Secretary-Treasurer, H. W. Smith; Executive Committee, Messrs. A. L. Broomall, G. Meedman, J. V. Peters, W. L, Shafer. Subject of meeting: "The Advantages of Interconnecting Industrial Power Plants." Authors: E. C. Stone, Duquesne Light Co., J. D. Thomas, West Penn Power Co.. F. C. Hamher, Westinghouse Elec. & Mfg. Co. Discussion was entered into by Messrs. Smith, Harvy, Kelly, Stoltz and Funck. Attendance 54.

Portland.—June 8, 1920, University Club. Annual dinner meeting. Election of officers as follows: Chairman, W. D. Scott; Secretary, W. C. Heston; Executive Committee, C. P. Osborne and O. L. LeFever. A talk on the subject of meterology was given by Mr. Edward Wells, Meterologist in charge of the Portland Station. Attendance 45.

St. Louis.—June 7, 1920, Engineers Club. Business meeting followed by presentation of paper on "The Broader Application of Engineering Methods" by Mr. B. H. Peck, General Manager of the Southern Illinois Light & Power Co. Attendance 63.

Spokane.—May 21, 1920, Davenport Hotel. Annual Meeting. Election of officers as follows: Chairman, R. S. Daniels; Secretary-Treasurer, L. J. Pospisil; Executive Committee, D. F. Henderson, B. M. Merrill and John B. Fisken. Subject of meeting: "Some Notes on Public Utilities Valuation." Speaker: Mr. Chas. A. Lund, Distribution Engineer of the City of Tacoma. Attendance 37.

PAST BRANCH MEETINGS

University of Cincinnati.—May 29, 1920, Chester Park Club House. Banquet. Reading of annual report and awarding of prizes for the best student papers. Professor Hoffmann acted as toastmaster. Toasts were given by Messrs. Wilson, Norton, Rodi, Osterbrock, Oster, Thomas, Nycum, Manson and Louis. Election of officers took place as follows: Chairman, R. S. Redmon; Vice-Chairman, G. C. Brown; Treasurer, Sec. 1, John Doran, Sec. 2, G. T. Addiston; Secretary, Professor C. B. Hoffmann. Attendance 67.

School of Engineering of Milwaukee.—June 18, 1920. Annual report was read, and election of officers as follows: Chairman, F. A. Kartak; Vice-Chairman, G. D. Rick; Secretary, L. F. Greve; Treasurer, C. E. Buchan. Attendance 50.

University of Notre Dame.—May 24, 1920, Engineering Building. Subjects: "Faraday and Maxwell, Their Part in the Development of the Science of Electricity" by D. Fitzgerald; "A Hydroelectric Power Plant to Supply Energy to a Paper Mill" by O. Ruzek. Attendance 23.

June 9, 1920. The Oliver Hotel. Annual Banquet. Addresses were given as follows: "The Development of the Department of Electrical Engineering at Notre Dame" by Rev. James Burns; "The Electrical Science and the Students of Engineering" by Rev. Thomas Irving; "A Survey of the Work of the A. I. E. E. Branch at Notre Dame" by Professor Caparo; "What is expected of Young Engineers" by Professor Benitz. Attendance 30.

Oregon State Agricultural College.—June 3, 1920. Election of officers as follows: Chairman, Roy C. Avrit; Vice-Chairman, Samuel Doukas; Secretary-Treasurer, Walter D. Olson. Attendance 14.

Stanford University.—May 3, 1920. Report of membership committee and other business. Attendance 17.

June 8, 1920. Illustrated lecture on "Super-sound" by Professor H. J. Ryan. Attendance 37.

University of Washington.—June 1, 1920, Forestry Hall. Subject: "The Long Lake Plant of the Washington Water Power Company and the Proposed Skagit River Development by the City of Seattle." Speaker: C. F. Uhden, City Engineer's Office. Attendance 35.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JUNE 30, 1920

Addis, Judd, Clerk, Westinghouse Elec. & Mfg. Co., 1400 Alaska Bldg., Seattle, Wash.

Alender, Walter A., Traveling Electrical Inspector, Swift & Co., Union Stock Yards; res., 5525 S. Paulina St., Chicago, Ill.

Almquist, Paul B., Partnership, Western Tool Mfg. Co.; res., 822 So. Wabash Ave., Chicago, Ill.

Anderson, Burt T., Asst. Signal Engineer. Delaware, Lackawanna & Western Railroad Company, 312 Adams Express Bldg., Hoboken; res., 28 Salter Place, Maplewood, N. J.

Anderson, John F., Dispatcher, Hydro-Electric Power Commission of Ontario, Belleville, Ont.

Anderson, Russell E., Engineering Draftsman, H. M. Byllesby & Co., 208 S. La Salle St., Chicago, Ill.

Andresen, Hilmar, Bridge Designing Engineer, City of Chicago, 2001 City Hall Bldg.; res., 5024 N. Sawyer Ave., Chicago, Ill.

Andrews, Clyde B., Radio Electrician, Pearl Harbor Navy Yard, Pearl Harbor, Oahu; res., 1424 Victoria St., Honolulu, T. H.

Anglemyer, Wilbur J., Research Engineer, Kellogg Switchboard & Supply Co., Adams & Aberdeen Sts., Chicago, Ill.

Anson, Stuart M., Sales Engineer, Westinghouse Elec. & Mfg. Co., 1012 Park Bldg., Worcester, Mass.

Arenberg, Albert L., Illuminating Engineer, Central Electric Co., 316 S. Wells St., Chicago, Ill.

Argabrite, Harry H., Stores Manager, Western Electric Co. Inc., 1425 Curtis St., Denver, Colo.

Arnold, Samuel, 3rd, Electrical Engineer, American Bridge Co., Ambridge; res., 158 Dixon Ave., Ben Avon, Pittsburgh, Pa.

Bailey, Walter L., Asst. Electrical Engineer, Morgan & Wright; res., 449 Lenox Ave., Detroit, Mich.

Bair, D. Arthur, Asst. Chief Draftsman, Distribution Division, Commonwealth Edison Co., Chicago; res., Drexel Ave., La Grange, Ill.

Barmack, Boris J., Engineer, Commonwealth Edison Co., 72 W. Adams St.; res., 1124 S. Richmond St., Chicago, Ill.

Bason, George F., Instructor, Electrical Engineering Dept., Sibley College, Cornell University; res., 1007 E. State St., Ithaca, N. Y.

Bateman, Sidney J., Load Dispatcher, Essex Power Station, Public Service Electric Co.; res., 830 Mt. Prospect Ave., Newark, N. J.

Bates, Albert Wood, Manager, Western Electric Co., Inc., New Haven, Conn.

Batsel, Max C., Radio Engineer, Signal Corps, U. S. A., Camp Alfred Vail, N. J.

Battern, Algy Ross, Local Manager, Iowa Light, Heat & Power Company, Carroll, Iowa.

Bayer, Edward F., Jr., Inspector, Electrical Engineering Dept., Westchester Lighting Co.; res., 417 S. 4th Ave., Mt. Vernon, N. Y.

BEDFORD, LYNN N., Commercial Engineer, General Electric Co., 53 W. Jackson Blvd., Chicago, Ill.

BENDER, JOSEPH G., Patent Drafting Dept., Western Electric Co., 463 West St., New York, N. Y.

BERRY, THOMAS D., Supt., Engenia System, Hydro-Electric Power Comm. of Ontario, Toronto; res., Markdale, Ont.

BLISS, WILLIAM W., Transmission Engineer, The Pacific Tel. & Tel. Co., San Francisco; res., 6443 Hillegass Ave., Oakland, Cal.

BLYE, PAUL W., Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

BOUSKA, JAMES W., Foreman, Repairs & Electrical Equipment, Commonwealth Edison Co.; res., 2255 So. Springfield Ave., Chicago, Ill.

BOWDEN, WILLIAM C., Electrical Contractor, 2 Repper Ave., Middle Village, L. I., N. Y.

BOWMAN, HERMAN N., Engineer, Western Electric Co., 463 West St., New York, N. Y.

BRADLEY, DANIEL L., Electrical Contractor, 11 W. Main St.; res., 1449 Willow Street, Norristown, Pa.

BRADSHAW, GEORGE H., Foreman, Switchboard Dept., Hydro-Electric Power Commission, 42 Culp St., Niagara Falls, Ont., Can.

BRITTON, EMMET W., Associate Editor, *Journal of Electricity*, 531 Rialto Bldg., San Francisco, Cal.

BROCKMAN, FRANCIS C., Radio Engineer, General Electric Co.; res., 217 Walnut St., Roselle Park, N. J.

BROKMANN, JOHN, Supervisor, Repairs, Electrical Equipment, Commonwealth Edison Co.; res., 1519 Hollywood Ave., Chicago, Ill.

BROWN, HARRY C., Electrical Draughtsman, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Can.

BROWN, IRWIN E., Superintendent of Repairs, The Lehigh Valley Light & Power Co., Northampton; res., 1421½ Liberty St., Allentown, Pa.

BRUECKNER, JULIUS R., Works Manager, Gibb Instrument Co., 348 Palmer St. East, Detroit, Mich.

BUCK, KENDALL, Operating, White River Hydro-Electric Station, Puget Sound Power & Light Co., Dieringer, Wash.

BUFORD, PASCHAL, Agent, Western Electric Co.; Travis, Hayes, Williamson & Caldwell Co's., 208 W. 7th St., Austin, Texas.

BUNKER, EDMUND C., Chief Electrician, Power House, Charleston Consolidated Railway & Light Co.; res., 11 Radcliffe Place, Charleston, S. C.

BURGER, EDWARD J., Supt. of Distribution, Lorain County Electric Company, Lorain, Ohio.

BURNHAM, DAVID W., Electrical Draughtsman, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Can.

BUTLER, ABNER I., Construction Foreman, General Electric Co.; res., 152 E. Superior St., Chicago, Ill.

BUZZELL, HAROLD W., Testing Dept., Commonwealth Edison Co., 28 No. Market St.; res., 6136 Ellis Ave., Chicago, Ill.

CAMERON, JAMES R., Salesman, Westinghouse Elec. & Mfg. Co., Law & Commerce Bldg., Bluefield, W. Va.

CAMP, CLIFFORD R., Draftsman, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

CAMPBELL, LOUIS O., Construction Superintendent, General Electric Co., Monadnock Bldg., Chicago, Ill.

CARNAHAN, GROVE C., Foreman, W. A. Jackson Co., 760 Old Colony Bldg.; res., 6451 Greenwood Ave., Chicago, Ill.

*CATLETT, JAMES T., 4015 Meridian Ave., Seattle, Wash.

CERECEDO, JAVIER H., General Manager & Engineer, The Union Commercial Corp., and Cerecedo & Co., San Juan, P. R.

CHALLIES, JOHN B., Director of Water Power, Department of Interior, Ottawa, Canada.

CHAPEL, HARRIE D., Instructor, Milwaukee School of Engineering; res., 163 Mason St., Milwaukee, Wis.

CHAPPLE, EDWARD A., Electrical Mechanic, Toronto Hydro-Electric System; res., 89 Wroxeter Ave., Toronto, Ont.

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PORTER, LESLIE F., Engineer, Repeater Section, Western Electric Co. Inc., 463 West St., New York, N. Y.

POTTS, MELVIN, Electrical Engineer, Standard Steel & Bearings Inc., Plainville, Conn.

Potts Thomas R., Engineer, Southeastern Underwriters Association, Atlanta, Ga.

Puchstein, Albert F., Asst. Professor, Elec. Engg. Dept., Ohio State University, Columbus, Ohio.

Purdy, Fred R., Operating Dept., United Electric Light & Power Co.; res., 601 W 181st St., New York, N. Y.

Putnam, Arthur D., Engineer, Worcester Electric Light Co., 11 Foster St., Worcester, Mass.

Read, Lance, Service Engineer, Westinghouse Electric & Mfg. Co., 32 S. Peoria St., Chicago; res., 534 N. Court St., Rockford, Ill.

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Rees, Raymond J., Asst. Electrician, The Great Western Sugar Co., Brighton, Colo.

Reid, William M., Meter Inspector, Hydro-Electric Power Commission of Ontario, 8 Strachan Ave., Toronto, Ont., Can.

Reier, George Conrad, Development & Research Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

Reneker, Robert Lee, Electrical Engineering Dept., Ford Motor Co., Detroit; res., Royal Oak, Mich.

Reynolds, Frank J., Engineer, Hartford Electric Light Co., 266 Pearl St., Hartford, Conn.

Ribal, E. A. H., Secretary, Dearborn Electrical Construction Co. Inc., 27 West Kinzie St., Chicago, Ill.

Richey, Nelson R., Electrical Engineer, General Electric Co., Fort Wayne, Ind.

Riggs, Albert C., Supt., Line Construction, Puget Sound Power & Light Co., 7th & Olive Sts., Seattle, Wash.

Roberg, Philip, Research Engineer, National Carbon Co., Cleveland; res., 1377 Lakeland Ave., Lakewood, Ohio.

Roberts, Bruce W., Engineering Dept., Puget Sound Traction, Light & Power Co.; res., 813 W. 64th St., Seattle, Wash.

Robinson, Benjamin, Chief Electrician, Bristol Brass Corp., 122 6th Ave., Bristol, Conn.

Robinson, Harry W., Sales Engineer, Sprague Electric Works of General Electric Co., 1213 American Bldg., Baltimore, Md.

Robinson, Isaac R., Asst. Engineer, Public Works Dept., Wellington, New Zealand.

Rocky, Basil S. S., Transformer Engineer, Apparatus Sales Dept., Canadian General Electric Co. Ltd., 212 King St. West, Toronto, Ont.

Rockey, James K., Long Lines Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.; res., Ridgefield Park, N. J.

Rosenfeld, Benjamin, Sales Engineer, Roland Electrical Co.; res., 3201 Presbury St., Baltimore, Md.

Ross, Walter R., Asst. Design Engineer, Philadelphia Electric Co., 1000 Chestnut St.; res., 1800 N. Broad St., Philadelphia, Pa.

Rothwell, Hugh D., Asst. Engineer, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont.

Rubin, Maurice, Electrical Engineer, Public Service Commission, 1st District, 49 Lafayette St., New York. N. Y.

Rust, James E., Electrical Engineer, Kohler Bros., 111 N. Jefferson Ave., Chicago; res., 328 Prairie Ave., Park Ridge, Ill.

Ruxton, Thomas B., Leadingman Electrician, U. S. Navy Yard; res., 20 Columbia St., Portsmouth, N. H.

Salmon, S. H., Jobber & Dealer in Electrical Supplies, 50 Obispo, Havana, Cuba.

Sanders, Walter J., Asst. Operating Engineer, City of Chicago, 405 W. Chicago Ave; res., 6228 S. Winchester Ave., Chicago, Ill.

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Schafer, J. Peter, Research Engineer, Western Electric Co., 463 West St., New York, N. Y.

Schiller, Avery, R., Electrical Engineer, John A. Stevens, 904 Sun Bldg., Lowell, Mass.

Schmid, Charles F., Technical Asst., Electrical Testing Laboratories, 80th St. East End Ave., New York; res., 475 Gramatan Ave., Mt. Vernon, N. Y.

Schoening, Edward M., Electrical Foreman, Pullman Co.; res., 9222 Houston Ave., Chicago, Ill.

Schuler, Louie L., Engineer, Haughton Elevator & Machine Co.; res., 405 Prescott St., Toledo, Ohio.

Schuler, William A., Engineer, Western Electric Co., 463 West St.; res., 32 St. Nicholas Place, New York, N. Y.

Schwaner. Robert M., Inspecting Engineer, Westinghouse Elec. & Mfg. Co.; res., 1937 Daly Ave., New York, N.Y.

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Scott, Fred J., Meter Tester & Armature Winder, Washington Water Power Co.; res., 2809 W. Mallon Ave., Spokane, Wash.

Seaman, George B., Construction Engineer, General Electric Co., Monadnock Bldg.; res., 11141 Esmond St., Chicago, Ill.

Seefield, Charles W., Clerk, Meter Dept., Puget Sound Power & Light Co.; res., 2 Smith St., Seattle, Wash.

Seely, Roy A., Engineer, Western Electric Co., 463 West St.; res., 611 W. 114th St., New York, N. Y.

Seem, Warren P., Gen. Supt. of Throwing, The Schwarzenbach Huber Co., Altoona, Pa.

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Sharpe, Victor L., Foreman, Sprague Electric Works of General Electric Co., Bloomfield; res., 739 Springdale Ave., E. Orange, N. J.

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*Shea, Timothy E., Instructor in Physics, Massachusetts Institute of Technology, Cambridge; res., 49 Worcester St., Newton Upper Falls, Mass.

Sheatsley, George W., Electrician, Ozark Coal Mining Co., Cumberland; res., 1210 South 8th St., Tacoma, Wash.

Shipp, James E., Apparatus Sales Dept., Motor Section, Canadian General Electric Co., Ltd.; res., 456 Gladstone Ave., Toronto, Ont.

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Sims, William F., Field Engineer, Generating Stations, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

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Sinclair, Ovid E., Inspector, Public Service Co. of Northern Illinois, Crystal Lake, Ill.

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Skibbe, Fred F., Electrical Draftsman, Manufacturing Dept., Pullman Co.; res. res., 7245 Champlain Ave., Chicago, Ill.

Skrainka, Walter J., Electrical Engineer, Wagner Electric Mfg. Co.; res., 4235 Lindell Blvd., St. Louis, Mo.

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Smith, Frederic, Div. Supt. of Construction, The Pacific Tel. & Tel. Co., 835 Howard St., San Francisco, Cal.

Smith, Fred W., Electrical Engineer, The Robbins & Myers Co., Springfield, Ohio.

Smith, James C., Commercial Manager, The Virginian Power Co., Charleston, W. Va.

Smith, Marvin W., Designing Engineer. Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1105 Trenton Ave., Wilkinsburg, Pa.

SMITH, ROBERT W., Engineering Asst., Engineering Dept., Bell Telephone Co. of Pennsylvania, 416 7th Ave., Pittsburgh, Pa.

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SNOW, FRANK S., Electrical Draftsman, U. S. Navy Yard; res., 170 Gate St., Portsmouth, N. H.

SNOW, WILBER C., Power Solictor, City of Seattle Lighting Dept., 204 County-City Bldg.; res., 418 24th Ave. South, Seattle, Wash.

SNYDER, FRED H., Electrical Operating Engineer, City of Chicago, 405 W. Chicago Ave., Chicago, Ill.

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STANG, WILLIAM H., Inspection Engineer, Lehigh Power Securities Corp., Hunsicker Bldg., Allentown, Pa.

STARIN, MARTIN W., Special Apprentice, Van Nest Electrical Shops, N. Y., N. H. & H. R. R.; res., 2078 Boston Road, New York, N. Y.

STEADMAN, HAROLD C., Sales Engineer, Cutler-Hammer Mfg. Co., 1238 Guardian Bldg., Cleveland, Ohio.

STEELE, FRANK W., A. C. Engineering Dept., British Thomson-Houston Co. Ltd.; res., 133 Murray Road, Rugby, England.

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STODDARD, FRED M., Chief Electrician, South Covington & Cincinnati Street Railway Co., Cincinnati, Ohio.

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STRONG, ALBERT E., Chief Inspector, Kellogg Switchboard & Supply Co., Adams & Aberdeen Sts., Chicago, Ill.

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*THOMPSON, STEPHEN W., Sales Engineer, Century Electric Company, St. Louis, Mo.

TILLINGHAST, THEO. V., Chief Clerk, P. L. & M. Dept., Pullman Co., Pullman Trust & Savings Bank, Chicago, Ill.

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TOYER, HARRY EDWARD, Asst. Supt., Hydro Plant, Winnipeg Electric Railway Co., Pinawa, Manitoba.

TRAFERT, ARCHIE WILSON, Railway Sales Agent, General Electric Co., Colman Bldg., Seattle, Wash.

TRACY, EDWARD R., Switchboard Engineer, The Pacific Tel. & Tel. Co., 503 Sheldon Bldg., San Francisco, Cal.

TRUEAX, CLYDE P., Electrical Engineer, Condron Co., 1433 Monadnock Bldg.; res., 5633 Cottage Grove Ave., Chicago, Ill.

TURNER, EDWARD E., Asst. Chief Engineer, Lehigh Valley Light & Power Co., Hauto, Pa.

UNDERHILL, ARTHUR W., JR., Engineering Dept., Niagara, Lockport & Ontario Power Co., 1638 Marine Bank Bldg., Buffalo, N. Y.

UPSON, CLAIR P., Electrical Draftsman, Tennessee Coal, Iron & R. R. Co.; res., 802 Tuscaloosa Ave., Birmingham, Ala.

VAN BUSKIRK, JAMES, District Manager, Moloney Electric Co., 431 So. Dearborn St., Chicago, Ill.

VANHALANGER, L. JOSEF, Electric Service Engineer, Westinghouse Elec. & Mfg. Co.; res., 2103 Lawrence Ave., Chicago, Ill.

VAN RENNES, CORNELIS, Designing Engineer, Delco Light Co., Taylor St.; res., 35 Illinois Ave., Dayton, Ohio.

VANSANT, SOMERS S., Electrician in Charge, American Sugar Refinery Co.; res., 225 Warren St., Jersey City, N. J.

VIOL, WALTER E., Telephone Equipment Engineer, Western Electric Co., 463 West St., New York, N. Y.

WAGNER, CHARLES F., Research Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 812 Cedar Ave., N. S., Pittsburgh, Pa.

WALKER, FREDERICK, Draftsman-Engineer, Canadian Westinghouse Co., Hamilton, Ont., Can.

WALKER, RICHARD, Inspector, Engineering Dept., South Eastern Underwriters Association, Atlanta, Ga.

WALL, J. VAN RENSSELAER, Engineer, Tel. Systems Development Organization, Engineering Dept., Western Electric Co. Inc., 463 West St., New York, N. Y.

WALLACE, GEORGE A., Lecturer in Electrical Engineering, McGill University, Montreal, Canada.

WALLIS, CHARLES R., Sales Agent, General Electric Co., 609 Colman Bldg., Seattle, Wash.

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WARNER, LESLIE THOMAS, Electric Light Dept., Town Hall; res., 289 Old Canterbury Road, Dulwich Hill, Sydney, N. S. W., Aus.

WEAN, LINCOLN E., Asst. Elec. Designer, Philadelphia Electric Co.; res., 1947 N. Camac St., Philadelphia, Pa.

WEEKS, ARTHUR W., Assistant Engineer, Gas Rectifiers, General Electric Co., W. Lynn; res., 9 Redington St., Swampscott, Mass.

WEST, CHARLES P., Draftsman, Cleveland Railway Co., Cedar Ave. Power House, Cleveland, Ohio.

WHITE, B. STUART, Electrical Supt., Fraser Cos., Ltd., Edmundston, N. B., Canada.

WINTER, BOYD W., Salesman, Westinghouse Elec. & Mfg. Co., Alaska Bldg., Seattle, Wash.

WINTERS, WALTER N., Plant Electrician, Gorden Oil & Gas Co., W. Tulsa, Okla.

WISWELL, FREDERICK G., Chief Draftsman, Puget Sound Power & Light Co., 605 Electric.Bldg., Seattle, Wash.

WOLF, HERBERT J., Assistant Plant Engineer, Pratt & Whitney Co., Hartford; res., 98 Gregory St., New Haven, Conn.

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WOOTTON, WILLIAM L., Graintex Company, Inc., 170 Madison Ave., New York, N. Y.

WRIGHT, GEORGE T., Student, Electric Traction Dept., L. B & S. C. Railway, Norwood Junction, London, Eng.

WRIGHT, PAUL L., Engineer, Western Electric Co. Inc., 463 West St.; res., 126 W. 104th St., New York, N. Y.

WRIGHT, VIRN J., Electrical Draftsman, U. S. Navy Yard; res., 52 Daniel St., Portsmouth, N. H.

YOSHIMURA, GEORGE U., Draftsman, Control Engineering Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

YOUNGER, MARTIN L., Electrical Engineer, General Electric Co., 19 Maud St., Pittsfield, Mass.

*ZINN, MANVEL K., Research Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

ZURICK, MARTIN J., Chief Electrician, The Great Western Sugar Co., Brighton, Colo.

Total 440

*Former enrolled students.

ASSOCIATES RE-ELECTED JUNE 30, 1920

BENTZ, HENRY C., Manager, Appliance Dept., St. Paul Electric Co.; res., 637 Marshall Ave., St. Paul, Minn.

CAHOON, WILLIAM H., Electrical Designer, Perin & Marshall, 50 Trinity Place, New York; res., 10 Hillside Court, Jamaica, N. Y.

CONNELL, C. W., Captain, A. S. A., U. S. Army, 1748 Q St. N. W., Washington, D. C.

DUNN, EDWARD J., General Superintendent, Indiana Utilities Co., 215 W. Maumee St., Angola, Ind.

ELLYSON, DOUGLAS WALKER, Electrical Engineer, General Electric Co., Monadnock Bldg., Chicago, Ill.

GIBBS, HARRY T., Ra lway Sales Engineer, Canadian Westinghouse Co., 1207 Bank of Hamilton Bldg., Toronto, Ont.

MCADAM, CLARENCE E., Engineer in Charge of Power Plant, Visayan Refining Co., Cebu, Cebu, P. I.

TOLMAN, CLARENCE M., Electrical Engineer, Moose Mountain, Ltd., Sellwood, Ontario, Can.

VAITSES, GREGORY S., Chief Electrical Tester New York Shipbuilding Corp., Camden; res., 308 Boulevard, Pitman, N. J.

MEMBERS ELECTED JUNE 30, 1920

BENHAM, FRANK A., Engineer, New England Tel. & Tel. Co., 50 Oliver St., Boston, Mass.

BURROWS, ROBERT PENN, Secretary & Treasurer & Sales Engineer, The Electric Sales& Engineering Co., 815-23 Prospect Ave,. Cleveland, Ohio.

CARROLL, PENN LEARY, Lieut-Comdr., U. S. Navy; Chief Engineer, U. S. S. New Mexico, Navy Dept., Washington, D. C.

CHU, YU MAI, Asst. Engineer, Acting Chief Engineer, Kwongtung Tramway Co., The Bund, Canton, China.

CLAMER, GUILLIAM H., 1st Vice-Pres. & Secy., The Ajax Metal Co., Frankford Ave. & Richmond St., Philadelphia, Pa.

CRAIG, BERRYWICK S., Electrical Engineer, The Texas Co., Port Arthur, Texas.

EWING, SYDNEY E. T., Consulting Mechanical & Electrical Engineer, Consolidated Mines Selection Co. Ltd., Johannesburg, S. Africa.

GOODWIN, ALBERT G. T., Power Plant Engineer, Broken Hill Associated Smelters, Port Pirie, S. Australia

GRANT, HENRY W., Supt. of Railway, Pacific Northwest Traction Co. & Puget Sound International Railway & Power Co., Everett, Wash.

GUTHORN, SEYMOUR L., Electrical Engineer, Perin & Marshall, 2 Rector St. New York, N. Y.

HUIE, OLIVER J., Chief Engineer, Southern Bell Tel. & Tel. Co. & Cumberland Tel. & Tel. Co. Inc., 78 Pryor St., Atlanta, Ga.

PEARSON, EDGAR FORD, Electrical Engineer, Northwestern Electric Company, Portland, Oregon.

POPE, HARRY B. Chief Substation Operator, Brooklyn Edison Co., Inc.; res., 34 Jefferson Ave., Brooklyn, N. Y.

SANDT, ROBERT A., Chief Engineer, Maxwell Engineering & Manufacturing Co., 61 Broadway, New York, N. Y.

SHEARER, HAROLD H., Engineer, General Engineering Staff' American Tel. & Tel. Co., 195 Broadway, New York, N. Y

STEPHENSON, LEIGH J., Private work on Electric Motors & Control Systems, 2157 West 107th St., Chicago, Ill.

TICE, FRANK H., Engineer & Estimator, George Woodward, Jr., 1723 Sansom St., Philadelphia, Pa.

WIDMARK, LAWRENCE E., Chief Engineer, Star Electric Motor Co., 124 Miller St., Newark, N. J.

WITHINGTON, SIDNEY, Electrical Engineer, N. Y. N. H. & H. R. R.; res., 86 Linden St., New Haven, Conn.

MEMBERS RE-ELECTED JUNE 30, 1920

BOYDEN, DAVIS S., Asst. Superintendent, Electrical Engineering Dept., The Edison Electric Illuminating Co. of Boston, 39 Boylston St., Boston, Mass.

RAE, FRANK B., Consulting Engineer, Avenue Bldg., 4500 Euclid Ave., Cleveland, Ohio.

TRANSFERRED TO GRADE OF FELLOW JUNE 30, 1920

BIBBINS, JAMES R., Supervising Engineer, The Arnold Co., Chicago, Ill.

BYLLESBY, HENRY M., President, H. M. Byllesby Co.; President Standard Gas & Electric Co., Chicago, Ill.

CALDWELL, HARRY L., Engr. of Elec. Distribution, Public Service Co. of Northern Illinois, Chicago, Ill.

CRAVATH, JAMES R., Member of firm, Fowle & Cravath, Chicago, Ill.

DEL MAR, WILLIAM A., Chief Engineer, Habirshaw Electric Cable Co., New York, N. Y.

ELLS, FREDERICK W., Chief Engineer, Northwestern Mfg. Co., Milwaukee, Wis.

FRASER, DANIEL M., Estimating Engineer, Canadian General Electric Co. Ltd., Toronto, Ont.

GEAR, HARRY B., Engr. of Distribution, Commonwealth Edison Co., Chicago, Ill.

HALL, CHESTER I., Engineer, Experimental Laboratory, General Electric Co., Fort Wayne, Ind.

KING, ARTHUR C., President, Illinois Appraisal Co., Chicago, Ill.

MILTON, TALIAFERRO, Manager, Chicago Office, Electric Storage Battery Co., Chicago, Ill.

MORTENSEN, NIELS L., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

MORTENSEN, SOREN H., Electrical Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

MOUNTAIN, JOHN T., Asst. to Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill.

REINHARD, LOUIS F., Chief Engineer, Mechanical Appliance Co., Milwaukee, Wis.

SCHWEITZER, EDMUND O., Chief Testing Engineer, Commonwealth Edison Co., Chicago, Ill.

SNOOK, H. CLYDE, Electrical Engineer, Western Electric Co., New York, N. Y.

WALLACE, JOHN N., Engineer in Australasia, Western Electric Co. Ltd., Wellington, N. Z.

TRANSFERRED TO GRADE OF MEMBER JUNE 30, 1920

ACKLAND, EUSTACE W., Managing Director, National Electrical & Engineering Co. Ltd., Wellington, N. Z.

ADAMS, HARRY H., Supt. Shops & Equipment, Chicago Surface Lines, Chicago, Ill.

ALLEN, N. L., Chief Electrical Engineer, American Zinc Lead & Smelting Co., Mascot, Tenn.

ANNETT, FRED A., Associate Editor, "Power," New York, N. Y.

BACON, FRANK R., President, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

BAKER, HENRY S., In Charge Detail Apparatus, Ontario Power Co., Niagara Falls, Ont.

BENSON, ROBERT J., Power Engineer, Wagner Electrical Mfg. Co., St. Louis, Mo.

BELL, WILLIAM I., Mechanical & Electrical Engineer, South Park Commissioners, Chicago, Ill.

BOOTH, WILLIAM K., Secretary & Chief Engineer, Booth Electric Furnace Co., Chicago, Ill.

BOWMAN, DONALD, Engineer of Apparatus & Materials, Commonwealth Edison Co., Chicago, Ill.

BRACK, G. S., Electrical Engineer, The Sanitary District of Chicago, Chicago, Ill.

BRITTON, JOHN A., Vice-President & General Manager, Pacific Gas & Electric Co., San Francisco, Cal.

BROWN, CARLTON E., Meter Engineer, Commonwealth Edison Co., Chicago, Ill.

BURR, FRANK D., Power Engineer, Denver Gas & Electric Light Co., Denver, Colo.

CLINGERMAN, BYRON H., Managing Power Engineer, B. F. Goodrich Co., Akron, O.

CRELLIN, EARLE A., Electrical Engineer with Leland S. Rosener, San Francisco, Cal.

CURTIS, LESLIE F., Asst. Professor of Electrical Engineering, University of Washington, Seattle, Wash.

D'HUMY, FERNAND E. Central Office Engineer, Western Union Telegraph Co., New York, N. Y.

DU VALL, W. CLINTON, Associate Professor of Electrical Engineering, University of Colorado, Boulder, Colo.

EDWARDS, STANLEY R., Editor, "Telephony," Chicago, Ill.

FLANDERS, MILTON M., Charge Dept. of Electrical Tests, Bliss Electrical School, Washington, D. C.

FLEET, ARTHUR H., Manager, Specialty Dept., Cutler-Hammer Mfg. Co., Milwaukee, Wis.

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GILLESPIE, FONTAINE M., Chief Operating Engineer, Riegos y Fuerza del Ebro, Barcelona, Spain.

GILMAN, RALPH E., Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

GROWDON, JAMES P., Asst. General Superintendent, Northwestern Electric Co., Portland, Ore.

GUILFORD, WILLIAM S., Director, Griffin Engineering Co. Ltd., Capetown, S. Africa.

HUBBARD, FRANK H., Patent Attorney, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

JACKSON, WILLIAM A., President, W. A. Jackson Co., Chicago, Ill.

JAMES, WILLIAM F., Sales Engineer, Westinghouse Electric & Mfg. Co., Philadelphia, Pa.

JOHNSON, ALVIN W., Elec. Engr. in Charge General Construction, General Electric Co., Chicago, Ill.

KAMMERMAN, JOHN O., Asst. Professor of Electrical Engineering, University of Wisconsin, Madison, Wis.

LAUE, GILBERT E., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

LOCKE, DEAN J., Electrical Engineer, with Albert S. Richey, Worcester, Mass.

LODYGUINE, ALEXANDER, Inspector Incoming Electrical Material, Sperry Gyroscope Co., Brooklyn, N. Y.

LUNN, ERNEST, Chief Electrician, The Pulman Co., Chicago, Ill.

MAVITY, VICTOR T., Electrical Engineer, Braden Copper Co., Rancagua, Chile, S. A.

MCHENRY, MORRIS J., Manager, Walkerville Hydro-Electric System, Walkerville, Ont.

MORSE, ROBERT E., Engineer-in-Charge, Henry R. Kent & Co., Rutherford, N. J.

NYE, HENRY V., Special Sales Engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

O'CONNOR, ALBERT, Manager, Switchboard Dept., Westinghouse Elec. & Mfg. Co., Boston, Mass.

OSTRANDER, JOHN K., Electrical Engineer, Dwight P. Robinson & Co., New York, N. Y.

PARKER, ROSS I., Apparatus Sales Dept., General Electric Co., Chicago, Ill.

PETROWSKY, JOHN F., Designing Engineer, A. C. Engineering Dept., Crocker-Wheeler Co., Ampere, N. J.

REINHARD, GUSTAV A., Asst. Chief Engineer, Mechanical Applicance Co., Milwaukee, Wis.

RUSSELL, FRANK J., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

SARA, RICHARD A., Partner, C. A. Sara, Montreal Que.

SCHOU, THEODORE, Chief Engineer, Ideal Electric & Manufacturing Co., Mansfield, O.

SEIBERT, WILLIAM J., Asst. Chief Electrician, General Electric Co., Erie, Pa.

SPENCER, FREDERICK A., Professor of Electrical Engineering, Norwich University, Northfield, Vt.

TODD, WILLIAM B., Asst. Electrical Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del.

TUTTLE, ELBERT B., Asst. Engineer, Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.

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WATERHOUSE, JAMES K., Supt. L. I. City District, N. Y. & Queens Electric Light & Power Co., Long Island City, N. Y.

WATT, GEORGE Y., Century Electric Co., St. Louis, Mo.

WHITNEY, RICH D., Associate Professor of Electrical Engineering, Syracuse University, Syracuse, N. Y.

WILKINSON, KENNETH L., Charge Foreign Wire Relations, American Telephone & Telegraph Co., New York, N. Y.

WURTH, WILLIAM, Engineer Statistics, The Peoples' Gas Light & Coke Co., Chicago, Ill.

WYNNE, VALENTINE C., Consulting Engineer, Albany, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candiadates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1920.

Austin, Eugene H., Wilkes Barre, Pa.
Bauer, Ernst, Niagara Falls, N. Y.
Blodgett, Dan A., Flint, Mich.
Brualla, Francis, New York, N. Y.
Bryan, Frank A., Jr., Ft. Wayne, Ind.
Buys, Orville, Pittsburgh, Pa.
Caputo, Nicholas J., Brooklyn, N. Y.
Carr, William W., Wenatchee, Wash.
Chapman, Penrose E., (Fellow), St. Louis, Mo.
Chesterman, Francis J., Philadelphia, Pa.
Colt, Frank B., New York, N. Y.
Cootes, John C. R., Latouche, Alaska.
Denyes, Percy C., Cambellford, Ont.
Dick Herman J., Shelby, Ohio
Dobson, Harry V., Stockton, Cal.
Fitzsimons, Thomas, Philadelphia, Pa.
Gilmore, Martin L., Toronto, Ont.
Green, Leroy S., Baltimore, Md.
Greenhut, Frederick W., New York, N. Y.
Griffith, Lafayette F., (Member), Little Rock, Ark.
Guha, Devendra N., Newark, N. J.
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Surface Leakage as a Factor in Insulator Design

BY T. M. FEDER

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The various factors influencing surface resistance and methods of increasing it, are discussed. It is shown that the most economical way of decreasing the leakage is the addition of properly proportioned corrugations on the under side of the flange or skirt. Typical computations are given, showing the approximate increase to be expected when corrugations are added.

ONE of the most important problems to be met by the insulator designer is that of surface leakage, or as it is sometimes, known, creepage. Under service conditions insulators acquire a coating film of moisture, or dust, or both, of a more or less conducting nature. This permits a current to pass from the line to ground over the surface of the insulators. The importance of this feature is well recognized by operating men and is a subject of live interest as evidenced by the attention paid to it in the engineering press. The magnitude of this current depends mainly on the material of the conducting film, and to some degree upon the character of the insulator glaze, since these may control the thickness of the deposited film.

Surface leakage is detrimental in three ways:

First, there is an actual loss of power due to the wasted current. This is very small when compared to the total power transmitted, but it is, nevertheless, one source of lost efficiency. In a long line many insulators are connected in parallel and the total leakage represents a considerable energy loss in a year.

Second, the leakage current causes heating of the insulators. This is a source of trouble on lines insulated by conventional type units, causing rapid expansion and contraction of the unit followed by cracking and consequent electrical failure.

Third, if the leakage be great enough, flash-over will occur, followed by a power arc. The flash-over in itself may not be destructive, but the power arc will heat and crack the thin section of the conventional unit. Regions are known wherein it is necessary to wash insulators quite frequently to avoid shut-downs from this effect.

It is thus seen that leakage should be reduced to as low a value as possible; in other words, the surface resistance of a unit should be made as great as possible without sacrificing other features of design.

It is the purpose of this paper to investigate the methods of increasing this surface resistance. It will be seen, however, that the subject is one which does not lend itself readily to analytical treatment. We can but derive some of the qualitative relations which show the most economical arrangement of the given amount of material for a maximum surface resistance.

From a consideration of the fundamental equation $R = \frac{\rho\, l}{a}$ wherein, $\rho =$ the resistance per unit volume; $l =$ length of conducting path and $a =$ area of conducting path, it is obvious that there is but one way of increasing the surface resistance for a given thickness and character of conducting film, and that is to increase l, the length of the path the current must traverse in creeping from electrode to electrode.

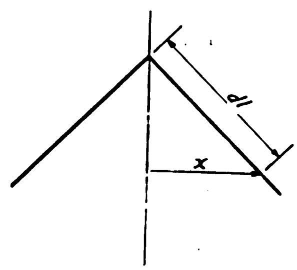


FIG. 1

It is also possible to decrease a, the area of the conducting film, but this change in a is an antagonistic function of other features of design, as it involves small unit diameters and consequently low flash-over values. The solution lies therefore, in adjusting l with as little increase in a as possible. This can be accomplished by either increasing the diameter or by the addition of corrugations and petticoats.

Consider the elementary conic insulator as shown in section in Fig. 1. Assuming a constant value ρ in the following discussions, the length of leakage path to any point on the surface is $d\, l$.

The radius to this point in the leakage path is x.

If t be the uniform thickness of the conducting layer, the cross-section of the conductor is $2\,\pi\, x\, t$.

$$\text{Total resistance } R = \frac{\rho\, l}{a} = \frac{\rho}{2\,\pi\, t}\int_0^L \frac{d\,l}{x} \qquad (1)$$

Given a unit with mathematical surfaces, equation (1) can be evaluated. For conventional types, however, this is impossible and the relation can best be shown by means of a surface resistance integral curve, as in Fig. 2. This being an integral curve, the area under the curve represents total resistance. For a unit not easily treated mathematically these areas are determined by measurement on the particular unit

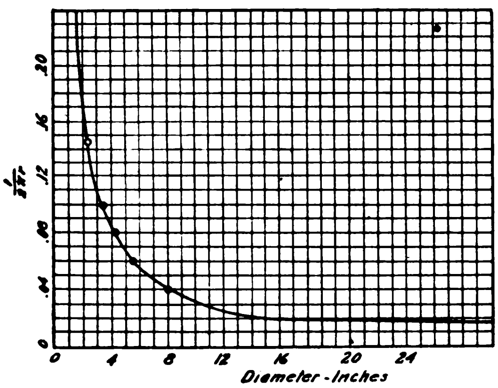


Fig. 2

studied. As shown by the shaded portions, the increase in total resistance gained by each equal increase in diameter becomes smaller and smaller as larger values of diameter are approached. Taking an extreme case, it is possible to increase the diameter without appreciably altering the value of R thereby. This shows how radically wrong it is to base the value of surface resistance on the diameter of the unit alone.

The explanation of this seeming paradox is quite

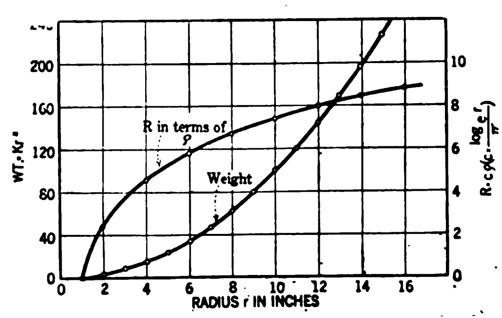


Fig. 3

simple. Surface resistance, as shown, is a function of length of leakage path and of diameter. As we increase length of leakage path l, we increase total resistance, but in so doing, as we increase the diameter, we decrease the total resistance, because of the effect of enlarging the area. Fortunately, as we increase the diameter the increase in length of leakage path attained increases the surface resistance at a greater rate than the increase in area of the conducting film lowers it. The effective increase in surface resistance follows a logarithmic curve, in accordance with the following equation:

Considering the upper surface only, $x = r = l$. Then equation (1) becomes

$$R = \frac{\rho}{2\,\pi\, t}\int_0^L \frac{d\,l}{x} = \frac{\rho}{2\,\pi\, t}\int_0^r \frac{d\,r}{r}$$

$$= \frac{\rho}{2\,\pi\, t}\log_e r$$

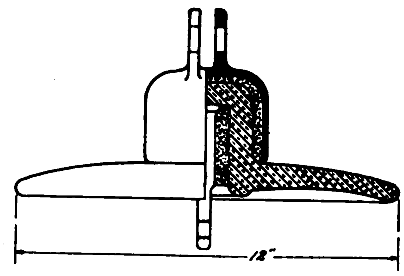


Fig. 4

For both upper and lower surfaces this relation becomes

$$R = \frac{\rho}{\pi\, t}\log_e r$$

For a given thickness of skirt the weight increases as the square of the radius. Graphically, these relations are shown in Fig. 3. Referring to this figure, assume a 12-in. disk (r = 6 in.) whose surface resistance we wish to increase by 20 per cent. For r = 6 in. $R = 0.58\,\rho$ and weight 36 K, where K is an arbi-

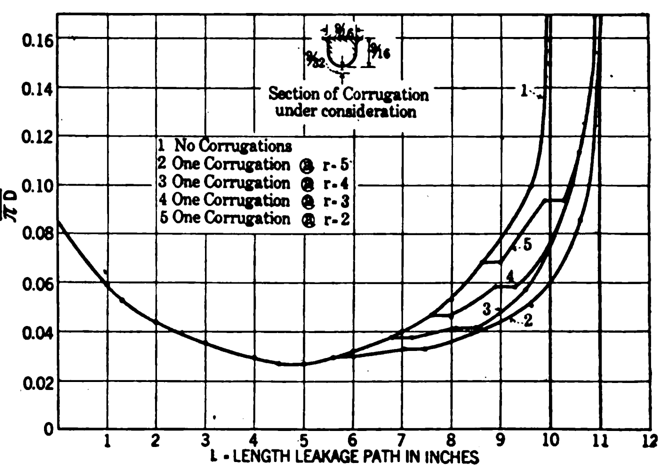


Fig. 5—Surface Resistance Integral Curves

Area under curves represents resistance of path

trary constant for the particular design. An increase of 20 per cent brings these values to $R = 0.696\,\rho$, r = 8.6 in., W = 74 K, an increase of 43 per cent in radius and 105 per cent in weight. Obviously the expense in material necessary to raise the surface resistance 20 per cent by increasing the diameter alone, is very high.

This procedure can be followed utilizing a conventional type unit as follows: Fig. 4 shows a conventional cap and pin type, 12-in. diameter suspension insulator with a smooth flange. The surface resist-

ance integral from this, computed by means of equation (1) is given as Curve (1) in Fig. 5.

In this curve, the resistance per inch of length of leakage path decreases from the cap to the end of the flange and then increases again on the under surface of the flange. The total area under the curve corresponds to $R = 0.50\ \rho$. Increasing this by 20 per cent means an addition of $0.1\ \rho$, corresponding in Fig. 3 to an increase in diameter of from 9 in. to 13 in. or 45.5 per cent and in weight, of 109 per cent, assuming the weight of cap and pin to remain constant. This is actually not true, since the weights of the cap and pin do increase with the diameter, making the increase in weight for a 20 per cent increase in surface by enlarging the diameter nearly 130 per cent.

It is obvious, then, that decreasing the surface leakage by making the unit larger, that is increasing the diameter alone, is a process of doubtful ecomonic value. There remains, then, the other scheme of increasing the surface resistance, and the one usually employed, *i. e.,* adding corrugations on the under side of the flange, increasing the length of leakage path without affecting the diameter of the unit.

Turning now to an investigation of the value of the corrugations and their best arrangement, assume the insulator shown in Fig. 5, placed on the under side of the flange at different radii.

The surface resistance integral curves for these conditions are shown in Fig. 5. The area under curve (1) as before mentioned, gives the resistance of the unit without any corrugations. Curve (2) is based on the same unit with one corrugation at a radius of 5 in.; curve (3) the same corrugation at a radius of 4 in., etc. Remembering that the length of leakage path is the same in all cases utilizing one corrugation, this shows strikingly that corrugations add an amount of resistance which varies inversely as the radius to the center line of the corrugation. The following table shows the approximate values of R.

Radius of corrugation	R	Increase in R	Per cent increase	Radius of smooth unit with equivalent R from Fig. 3
None	$0.50\ \rho$	....	....	4.5 in.
5 in.	$0.686\ \rho$	$0.186\ \rho$	37	8.6 in.
4 in.	$0.73\ \rho$	$0.23\ \rho$	46	9.6 in.
3 in.	$0.795\ \rho$	$0.295\ \rho$	59	11.8 in.
2 in.	$0.85\ \rho$	$0.35\ \rho$	70	14.4 in.

Curve (1) of Fig. 6 shows the relation between the percentage increase in total resistance offered by one corrugation, and the radius to the center line of the corrugation, a straight-line variation. Curve (2) of the same figure shows the percentage increase in total weight caused by a single corrugation at various radii. From these curves we see that R can be increased by 70 per cent and weight only by 8 per cent by adding one corrugation at a radius of 2 in. An attempt to attain this same increase by simply enlarging the diameter would result in an absurd unit. The equivalent addition in radius corresponding to one corrugation at different radii is shown in Fig. 7. It is interesting to note that for the unit referred to, this curve is a rectangular hyperbola. Thus one corrugation at 4-in. radius is equivalent to changing a 12-in. disk to one of 22-in. diameter, considering only resistance gained, with corresponding increase in weights of 16 per cent and 240 per cent respectively for the gain by corrugation and increased diameter.

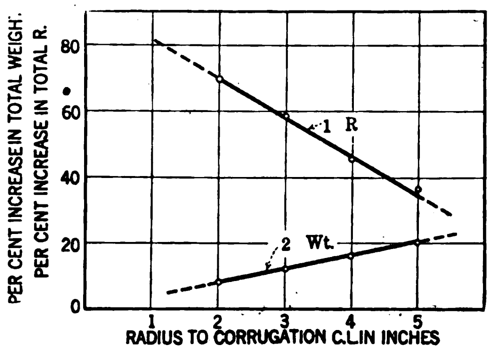


FIG. 6

The preceding discussion has purposely neglected the consideration of any of the other factors of design, of which surface resistance is but one item. However, certain conclusions present themselves which will hold good under any conditions of compromise found necessary by the designer. Surface leakage can be reduced in two ways; by a properly balanced design and by proper care in the field. A poorly designed unit may perform better than a well designed one in the matter of leakage if it is kept clean by periodic washing. In this respect, we must not forget that a deposited film of conducting material is cumulative. That is, a small film causes leakage and consequent heating of the insulator, which in turn evaporates any deposited moisture rapidly, causing it to leave its solid matter behind and so increasing the size of the original deposit and the leakage. A cold insulator will not evaporate the moisture rapidly, and will allow rain to wash the flange clear. The under surface, of course, will remain dirty until washed by the patrol. This is a function

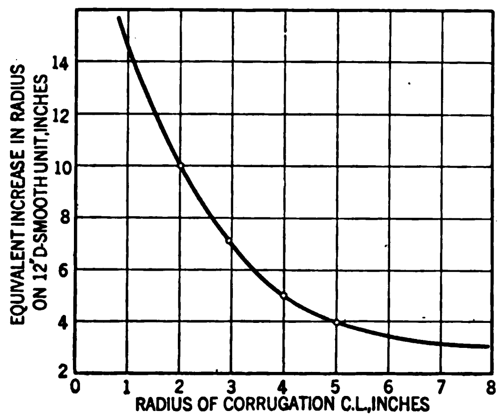


FIG. 7

of the operating engineer and not of the designer, but it is a great expense and it is the duty of all insulator designers to reduce as far as possible this burden on the operating engineer. It is only by a careful study of all such features of design that a rationally designed insulator can be produced that will meet the requirements of the operating engineer to the greatest degree.

The designer can do his part at the drafting table by making the diameter, and so the weight and cost, as small as consistent with other requirements, and the total resistance as large as possible, by the addition of properly proportioned corrugations of small diameter. The corrugations should be heavy enough to resist successfully shocks or power arc. Thin, deep corrugations are mechanically weak and should be avoided. A rationally designed unit has one advantage in surface resistance over the conventional type heretofore mentioned, which lessens the necessity for deep corrugations. In such a design, the body of the unit conforms with the flow lines of dielectric flux. Consequently the electrostatic stress along the surface of the body is everywhere tangential, and tends to throw off all particles of foreign matter which may otherwise lodge on it to form a conducting path. Thus the areas immediately around the electrodes are kept clean of all deposit and the surface resistance is a maximum. This is true of course, only in the consideration of the insulator in a dry condition.

It is hoped that this brief presentation of a very important factor in insulator design will lead operating engineers to a study of the distribution of material in insulator practise that will result in an improvement in the operating conditions of transmission lines in this respect.

Acknowledgments are due to Mr. W. D. A. Peaslee, Electrical Engineer of Jeffery-Dewitt Insulator Company for his many suggestions during the course of preparation of this paper.

FEDERAL ELECTRIC RAILWAYS COMMISSION

A unanimous report was made by the Federal Electric Railways Commission to President Wilson on August 24th, in which extensive reforms in the electric railway industry are recommended in order to restore public confidence and much needed credit. During the past year the electric railways have suffered severely and 48 companies went into receiverships. The War Labor Board made recommendations that the electric lines should increase wages $100,000,000 annually, but did not make any recommendation regarding increase of fares to meet the increasing costs of operation. The result is that the industry, representing six billions of capital, is in even more desperate condition than the steam railways.

The commission, which has been investigating the affairs of the railways for more than a year, makes some radical recommendations which are outlined in a dispatch to the New York *Times* as follows:

"Outstanding among the recommendations is that for the installation of the service-at-cost plan of operation. This plan, now operative in Cleveland, Cincinnati, Dallas, Montreal and other cities will, it is believed, remove the industry from the field of speculative gain, furnish rides at the lowest possible cost and restore credit and public confidence.

Primarily the plan provides for furnishing rides at actual cost, which shall govern the rate of fares, and for protecting the investor by guaranteeing a fixed return on an agreed valuation of his holdings.

Managements are advised that their primary duty is to serve the public with the highest efficiency at the lowest cost, with their cards face upward on the table, and not to use the industry as a means of obtaining profits beyond what may be necessary for upkeep, to pay a fair return upon the agreed value of the property and to secure the investment of funds further required.

The public duty is declared to be the supervision and control of railway properties, with the view of safeguarding the public interest and the allowance of such return upon the fair valuation of the property as may be agreed upon in the contract between the city and the company. By reason of such supervision the future attitude of the public should be one of friendliness and cooperation.

Employes it is said should have a living wage and humane hours of labor and working conditions, and a right to deal collectively with their employers, through committees or representatives of their own selection, but it is added that 'all labor disputes should be settled voluntarily or by arbitration and the award of such board should be final and binding on both parties.'

Other important declarations of the report are:

That public ownership and operation, generally speaking, are undesirable unless the results under private operation prove unsatisfactory, but the right of the public to own and operate all public utilities should be recognized and legal obstacles in the way of its exercise should be removed.

That extensions into outlying territory benefiting private property should be paid for by assessments on such property in proportion to the benefits received, and that the cost of such extensions should not be added to the valuation of the railroad property upon which a fair return is to be allowed.

That franchises should fix no limit as to the time they shall run nor the fares that may be charged.

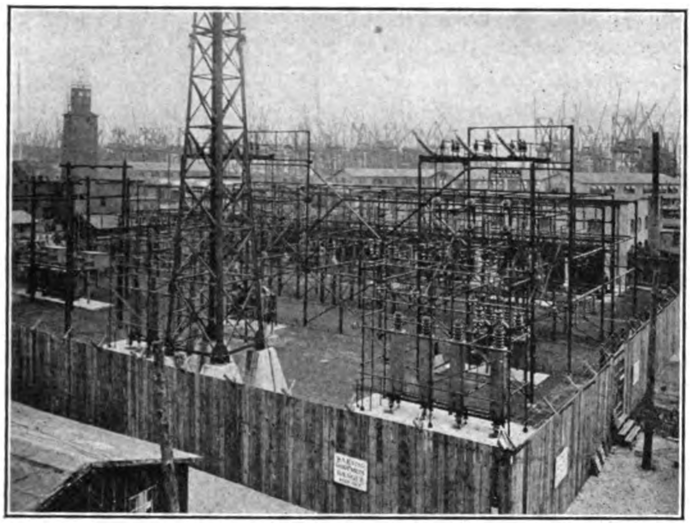
The commission emphasizes the importance of determining by arbitration or otherwise the fair value of the railway property 'as the basis for the financial return of the company,' and also as the basis upon which it may, if desired, be taken over by the municipality."

Features of the Substation at the Hog Island Shipyard

BY W. B. WEST

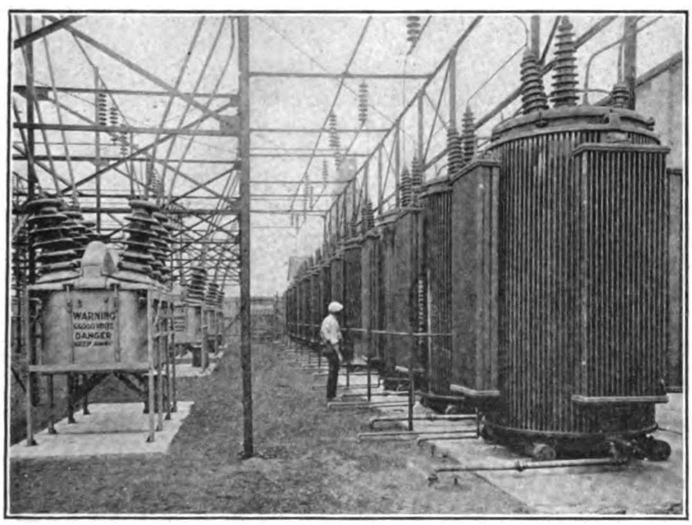
Hydroelectric Research Engineer, New York

THE Hog Island Shipyard, near Philadelphia, Pennsylvania, constructed as a war measure, and which is known all over the world as one of the largest shipyards in existence, is operated throughout by electrical power purchased from the Philadelphia



OUTDOOR 66,000-VOLT BUS STRUCTURE—MAIN SUBSTATION

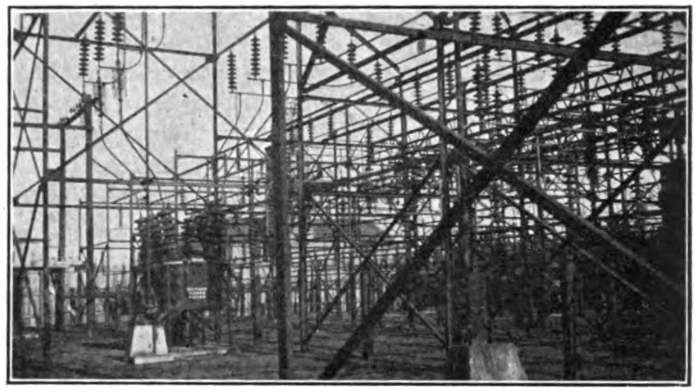
Electric Company and transmitted over a double-circuit, 66,000-volt stranded copper No. 00 tranmission line. There is also another single-circuit line operating at 13,000 volts. Both are three-phase circuits. At the main substation (shown in an accompanying illus-



TRANSFORMER BANK AND HIGH-TENSION OIL SWITCHES. MAIN SUBSTATION

tration) there are twelve General Electric transformers with a capacity of 2000 kv-a. each. The frequency throughout the system is 60 cycles per second. The primaries of the transformers are delta-connected, and the secondaries are Y-connected. Their temperatures were 55 deg. cent. when the writer was at the station in March, 1920. They are purely oil-cooled. Monthly tests are made of the oil in the transformers, and if the oil is below the 28,000 point it is filtered by a filter which is located on the interior of the substation. It too, is a standard G. E. type.

The 66,000-volt oil switches are arranged as shown in one of the illustrations. The bus structure is com-

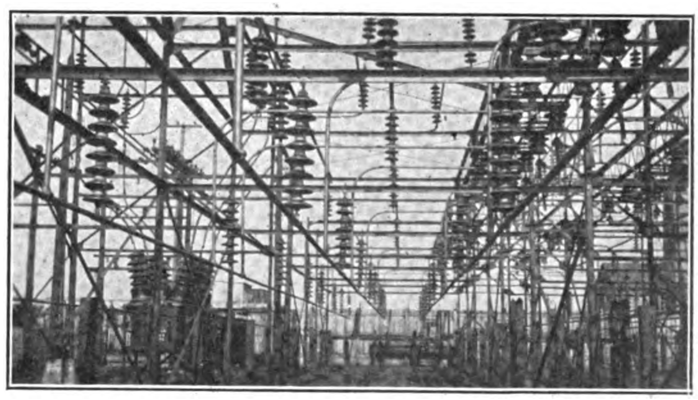


THE BUS STRUCTURE

posed of bronze coated pipes, 1¼ inches in diameter, suspended from eight-disk Ohio Brass insulators. The connections from all switches to the overhead bus structure are also 1¼-in. pipes.

The oil switches in the main substation are operated by electric motors ¼ h. p. each, using direct current at 110 volts pressure. This applies to three switches.

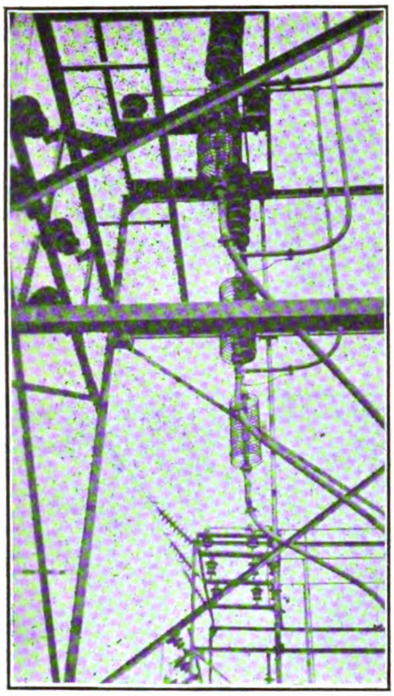
In the storage battery room there are 58 Gould storage cells which operate the oil switches and fire



A "GARDEN" OF ELECTRICAL EQUIPMENT

alarms. Each is capable of delivering 2½ volts maximum.

There is a private telephone exchange in the main substation. Trunk lines run from this P. B. X. exchange to the main telephone building. From the P. B. X. exchange telephone connections are made to the various plants throughout the yard which receive power from the main substation. Therefore, the op-



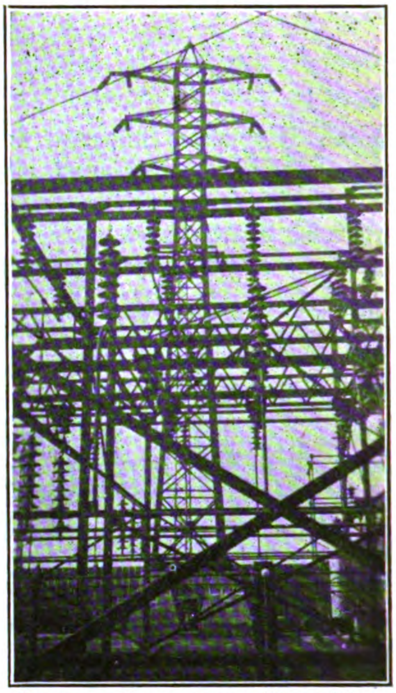
Details of Choke Coil Construction

eration of the entire system is not only under the control of the load dispatcher in the main substation, but men in the main office may also communicate with operators at the various plants.

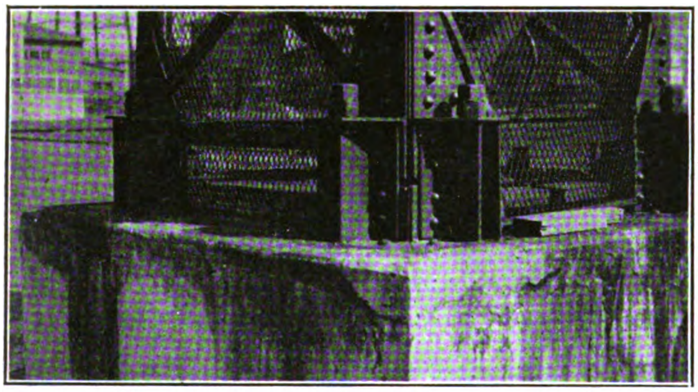
From the main substation power is distributed to the seven air compressor stations at a voltage of 4150, and to the pumping stations and other utilities. The compressor plants supply compressed air for the operation of riveters and other structural devices.

Construction was carried on under the greatest imaginable handicaps, as to isolation of location from transportation, bad drainage, weather conditions, and other causes coincident with the construction of the shipyard which was being carried on at the same time.

E. T. Smith who is Electrical Superintendent has immediate supervision of this station's operation. F. G. O'Neil is in charge of the Utilities Department.

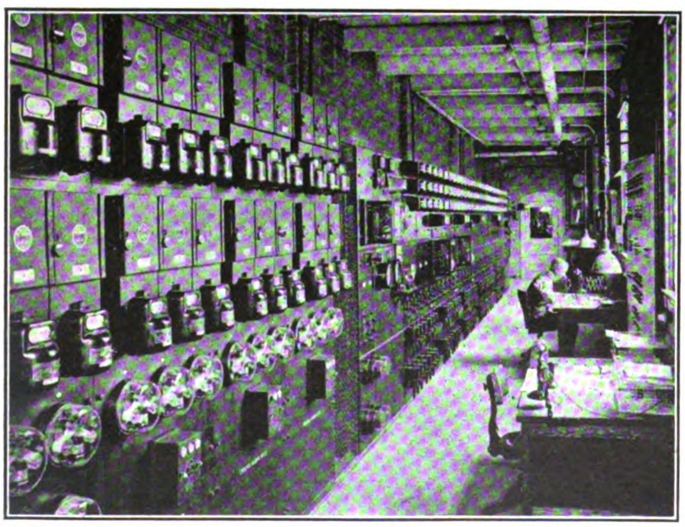


General View of the Main Dead End Transmission Tower

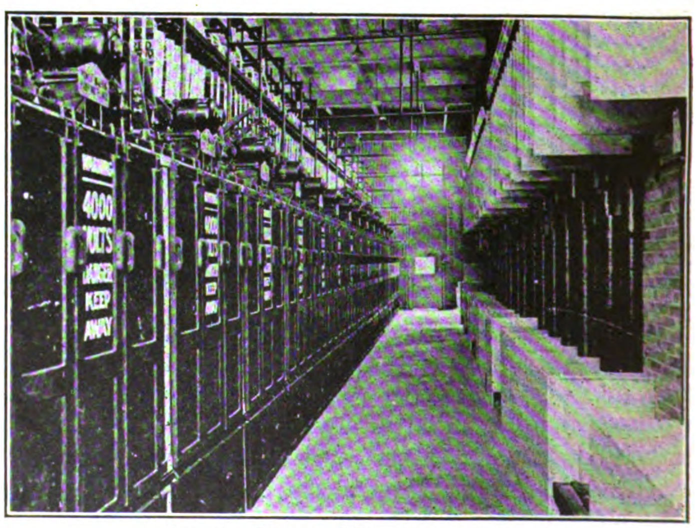


Close-up View of Typical Line Tower Showing Details of Construction

Close-up View of Main Dead End Tower Shown Inside Substation



Switchboard Room—Main Substation



Switch Room—Main Substation

High-Frequency Iron Losses

BY THOS. SPOONER

Electrical Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Data are presented giving the iron losses for five-mil, 4 per cent silicon steel sheet for a range of frequencies from 5000 to 50,000 cycles per second. An approximate separation of hysteresis and eddy current losses is made showing the result of skin effect on these losses.

A method of test is described which if desired could be used over a much wider range of frequencies than those indicated. The source of high-frequency supply was a new type of arc oscillator.

The probable accuracy of the results and the possible sources of error are discussed.

INTRODUCTION

WITH the rapidly increasing use of wireless apparatus it becomes more and more important to know the properties of the materials entering into the construction of such apparatus. In the design of wireless generators the iron losses of the magnetic circuit present one of the limiting features. The eddy current losses can of course be reduced by using thinner laminations, but a limit is soon reached beyond which it does not pay to go for several reasons, chief of which are that as the material becomes thinner the difficulties of rolling are greatly increased and that as the thickness is decreased the hysteresis losses increase. Five-mil silicon steel can be produced without much difficulty and for many applications does not have excessive eddy current losses. In this paper will be presented some iron loss data for five-mil 4 per cent silicon steel for a range of frequencies from 5,000 cycles to 50,000 cycles. The particular material from which these data were obtained had a thickness of 4.9 mils by micrometer, and of 3.9 mils as calculated from the weight and an assumed specific gravity of 7.5. The resistivity as calculated from the weight and the same assumed specific gravity was 62 michroms per cm³.

METHOD OF TEST

After considering various possible methods of test, it was decided to use a double calorimeter method somewhat similar to that used by Nusbaum*, with the additional feature, however, that arrangements were made to determine the induction at which the iron was operating as well as the exciting current. The high frequency supply was obtained from a tungsten arc oscillator devised by Dr. Rentschler of the Westinghouse Lamp Company. Referring to Fig. 1, this oscillator O was supplied with 500 volts direct current from a generator through a lamp bank of tungsten lamps and an Ammeter A_1. Across the arc was connected an oscillating circuit of paper condensers C_1 and a variable inductance L_1. Tapped across a portion of the inductance was a second tuned circuit consisting of a variable condenser C_2, inductance L_2, the thermal ammeter A_2, and the primary winding of the sample to be tested D_1. The object of introducing this second circuit was to damp out any harmonics which might be generated by the oscillator. Inductively coupled with the inductance of the sample circuit was wave meter W. The sample under test consisted of 24 grams of rings 1¾ in. outside diameter by 1¼ in. inside diameter punched from enameled five-mil steel. The sample was insulated with empire cloth tape, wound with a secondary winding of 60 turns of No. 30 magnet wire and a primary winding of 10 turns of No. 18 lamp cord. The secondary winding was connected to a portable electrostatic voltmeter V_2, designed by Dr. Compton of the Westinghouse Lamp Company. This instrument normally gave a deflection of about 10 cm. on a meter distance scale with 30

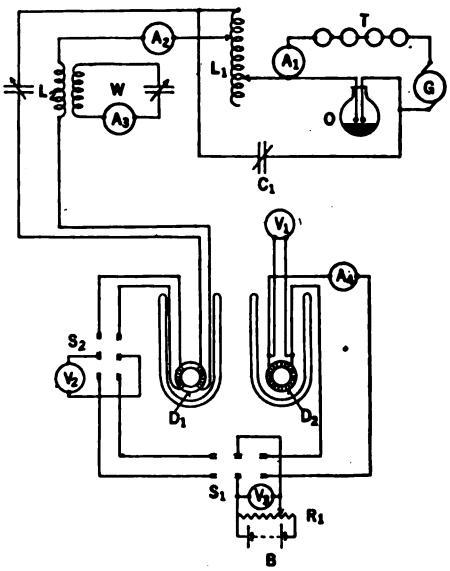


FIG. 1

volts applied. The sensibility was adjustable, however, by changing the level of the instrument. This voltmeter could be connected either to the sample or to a calibrating circuit by means of the switches S_1 and S_2. When connected to the calibrating circuit the voltage was read by means of voltmeter V_3. When switch S_1 was thrown to the right the heater coil D_2 was connected to the battery B. This heater coil was in intimate contact with some five-mil stampings exactly like those of D_1 and of the same weight. The heater coil was made of "advance" wire and was wound around about one-third of the rings. Each of the other thirds was placed outside of the heater coil and the whole insulated with tape in the same way that D_1 was insulated. Thus we had two samples, one of which was heated

*Hysteresis and Eddy Current Losses in Iron at Radio Frequencies, by C. Nusbaum, *Proceedings, Institute of Radio Engineers*, Feb. 1919.

by hysteresis and eddy currents and the other by the I^2R losses in the windings. The ease of escape of heat was about the same for the two samples. The I^2R losses in D_2 were measured by means of the voltmeter V_1 and the ammeter A_4.

The calorimeters, each of which contained one of the samples, consisted of two Dewar flasks about 2 ½ in. inside diameter by 7 in. high. These flasks were made at the same time and were practically identical as shown by cooling curves taken on them. The flasks were filled about two-thirds full of kerosene and each was provided with a stirrer. The equality of the temperatures of the calorimeters was determined by five pairs of copper-advance thermocouples connected differentially to a D'Arsonval galvanometer.

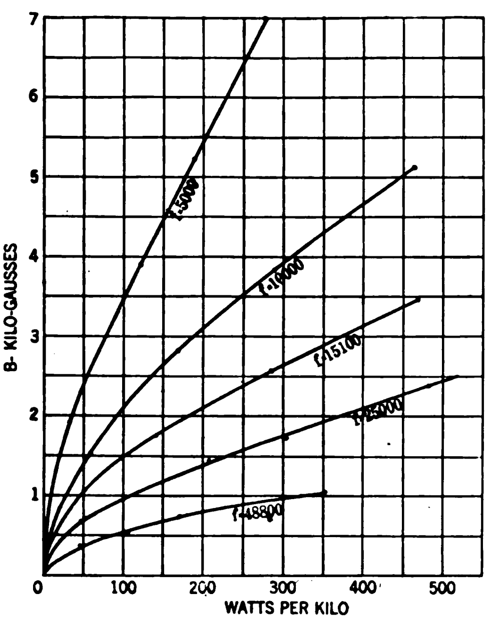


Fig. 2

Procedure

The method of operation was as follows: The oscillator was started by lowering the electrodes into the mercury and then slowly withdrawing them. This was done by tilting the oscillator bulb. The capacity of the sample circuit was adjusted approximately for the frequency desired as determined by calculation. The wave-meter was set for the desired frequency and then the inductance and capacity of the arc circuit adjusted for a maximum reading of the wave-meter. The tap of the inductance L was adjusted until the voltmeter V_2 read a value corresponding to the desired induction for the sample. After these adjustments were made it was found necessary usually to make no further changes except to adjust occasionally for V_2. This might have been done by moving the tap on the inductance but it would usually result in a change of frequency which had to be compensated for. Therefore this voltage adjustment was generally made by raising or lowering the electrodes of the oscillator with respect to the mercury bath by tilting the bulb. A considerable change of voltage could be obtained by this means without materially affecting the frequency. After a run was started the voltage, and therefore the induction, was kept as nearly constant as possible. At the same time current was applied to D_2 and varied until the differential thermocouple galvanometer showed that the two calorimeters were heating at the same rate. V_1 and A_4 were then read and the loss in sample D_1 could be calculated. The thermal ammeter A_2 gave the exciting current and the induction was calculated from the usual formula.

$$B = \frac{E \times 10^8}{4.44 f \times A \times N_2}$$

where E is the voltage, f is the frequency, A is the cross-section of the sample in sq. cm. as determined from the weight and an assumed specific gravity of 7.5 and N_2 is the secondary turns. To obtain the voltage values the electrostatic voltmeter was connected to the battery circuit, R_1 adjusted until the electrostatic instrument read the same as it had on the a-c. circuit and then the voltmeter V_3 read.

In connection with these tests it is interesting to note that in using the various frequencies the average maximum audible frequency of quite a number of observers was about 15,000. One observer in fact was able to adjust the frequency of the apparatus quite accurately at 15,000 due to the fact that his limit of audibility occurred at this point.

In order to eliminate any errors due to possible differences in the two calorimeters, the samples were interchanged at each induction and a second thermal balance obtained.

It was thought that there might be appreciable losses in the primary winding of the sample. In order to determine this point a ring of hard rubber having the same dimensions as the iron sample was wound like D_1, connected in series with the oscillator circuit and placed in one of the flasks. The other flask was left empty. No appreciable heating was produced at 25,000 cycles and two amperes after a period of several minutes. A difference of temperature of one deg. between the two calorimeters corresponded to a deflection of 17 cm. on the galvanometer scale.

In addition to the a-c. tests, ballistic loops were obtained on the sample for $B = 1$, 3 and 5 kilogausses and the hysteresis losses calculated.

Discussion of Results

Table I gives a summary of the test results.

Fig. 2 shows the relation between the induction in kilogausses and the total watt loss in watts per kilogram for 5000, 15,100, 25,000 and 48,800 cycles per second. The inductions are based on net section as calculated from the weight and an assumed specific gravity of 7.5 as mentioned above. If results in gross section are desired, they can be calculated from the space factor

which was about 0.75 for the enameled rings at a pressure of 50 pounds per square inch.

Fig. 3 gives the relation between the induction and the ampere turns per cm. of the exciting current.

Fig. 4 gives the relation between the watts per kilogram and the frequency for various inductions from 0.5 kilogausses to 5 kilogausses.

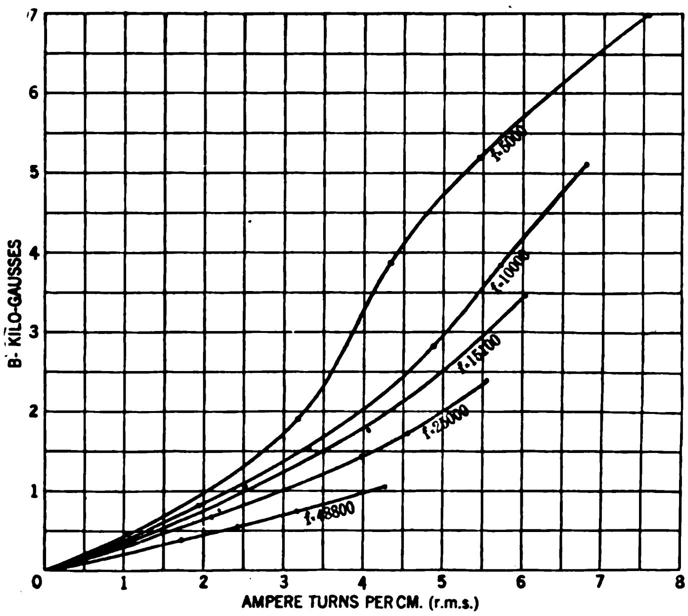


FIG. 3

Fig. 5 gives the relation between the induction and the hysteresis loss in watts per cycle per kilogram as determined from the ballistic loops. This figure also shows magnetization and permeability curves for the material.

Fig. 6 shows the relation between the watts per

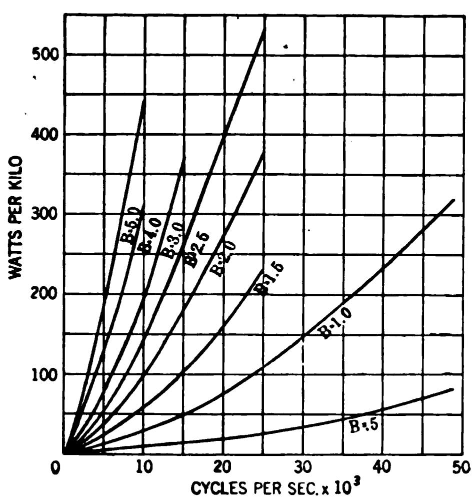


FIG. 4

cycle per kilogram and frequency. The circles on the zero frequency line indicate the ballistic results. It is evident that the relation between the watts per cycle and frequency is not a straight line at the higher inductions, at least as is the case at low frequencies, but has a definite convex tendency upwards. This is undoubtedly due to the skin effect as pointed out by Lloyd and Fisher*, and is explained by them as follows: "The short eddy current paths enclose a smaller flux, while the longest ones enclose the same.

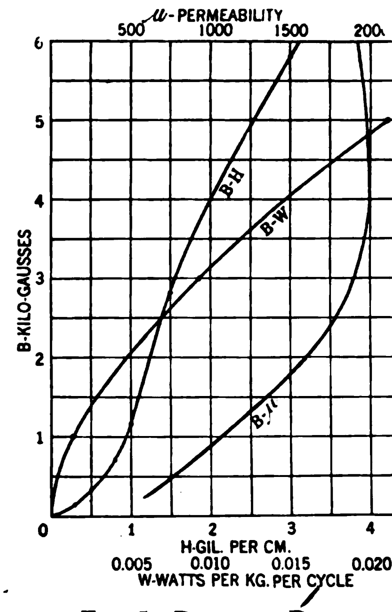


FIG. 5—BALLISTIC DATA

Hence, the average e. m. f. of the eddy current circuits does not increase as fast as the frequency."

Assuming the hysteresis loss as obtained from the

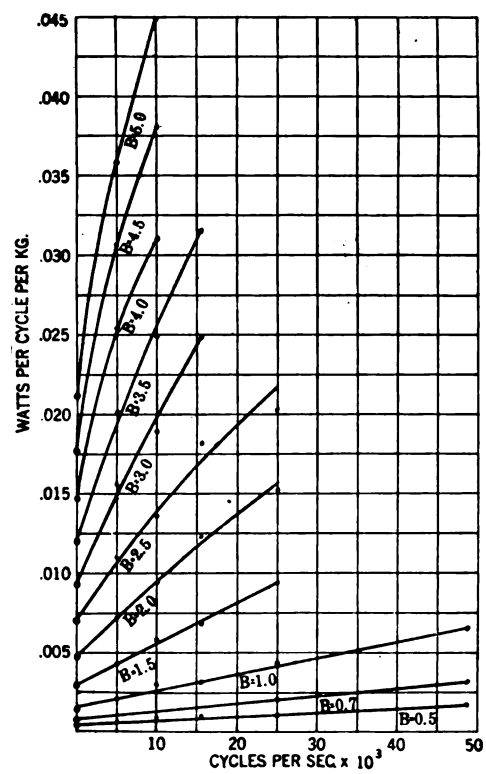


FIG. 6

ballistic tests, the eddy current losses were calculated and the hysteresis and eddy current values were plotted against the induction in kilogausses as shown by

*Bureau of Standards *Bulletin*, Vol. V, No. 4, p. 472-473.

Fig. 7. Next the logarithms of the eddy current losses were plotted against the logarithms of the frequency and the induction as shown by Figs. 8 and 9 respectively. The slopes of the curves are given by the numbers shown just below each line and are the mean

TABLE I

Frequency	B Kilogausses	Watts per kg.	Ampere turns per cm.*
5,000	1.90	33.8	3.17
	3.88	121.	4.33
	5.20	190.	5.45
	7.00	277.	7.57
10,000	.845	21.3	1.94
	1.51	58.1	3.33
	2.82	169.	4.87
	3.83	290.	5.72
	5.11	464.	6.79
15,100	1.05	50.7	2.51
	1.75	142.	4.06
	2.56	286.	5.06
	3.46	469.	6.03
25,000	.68	48.3	2.10
	1.43	208.	3.98
	1.71	305.	4.55
	2.38	483.	5.53
48,800	.37	46.7	1.73
	.53	106.	2.44
	.74	171.	3.17
	1.04	353.	4.27

*r. m. s. values of the exciting current.

values of the exponents. By this method of analysis it appears that the eddy current losses do not increase as fast as the square of either the induction or the frequency as of course would be expected from the data of Fig. 6. There is another factor however, which should be considered in making such an assumption,

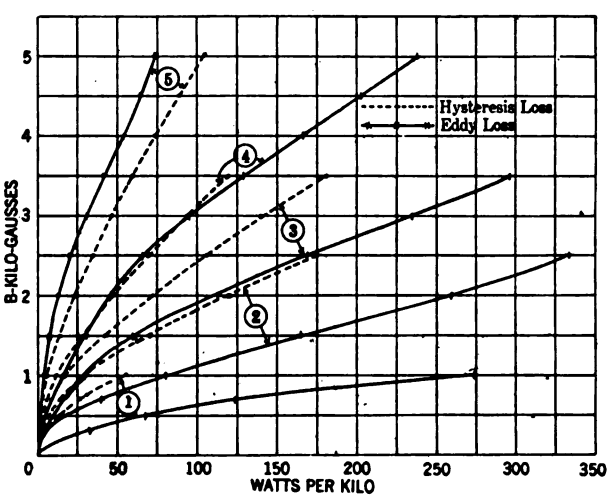


FIG. 7
1—48,800 Cycles. 2—25,000 Cycles. 3—15,100 Cycles. 4—10,000 Cycles. 5—5,000 Cycles.

namely the effect of the non-uniform flux on the hysteresis losses as a result of the skin effect. The actual hysteresis losses are higher than would be the case were the fluxes uniform. Therefore some of the losses which appear as eddy current losses are really hysteresis losses. This effect might be calculated approximately by using Steinmetz' formulas* for skin effect. But it was thought that the accuracy of the present data and the uncertainty as to what permeability values to use would not warrant the time necessary for these calculations as they would be somewhat tedious. Moreover this effect is not large as shown by a calculation of the induction at the centers of the sheet for an average induction of 2000 gausses and a frequency

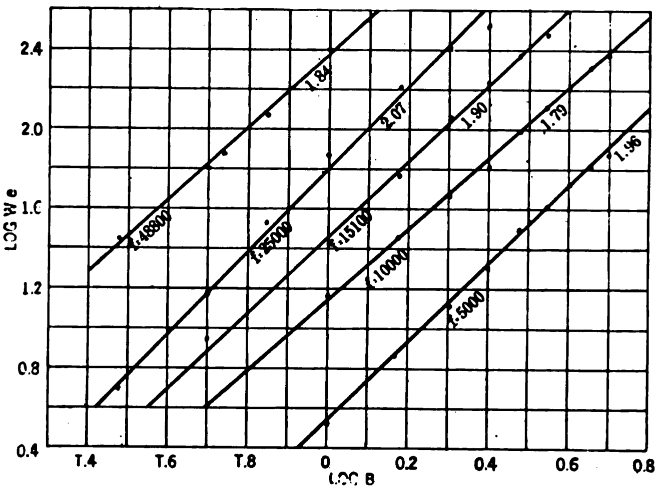


FIG. 8

of 25,000 cycles. As determined from the above mentioned formulas the center induction is 1980 or only 1.0 per cent lower than the mean induction. It seems quite certain that the eddy current losses do not increase as fast as the square of either the frequency or the induction. The reason for this as regards frequency has been pointed out by Lloyd and Fisher, as

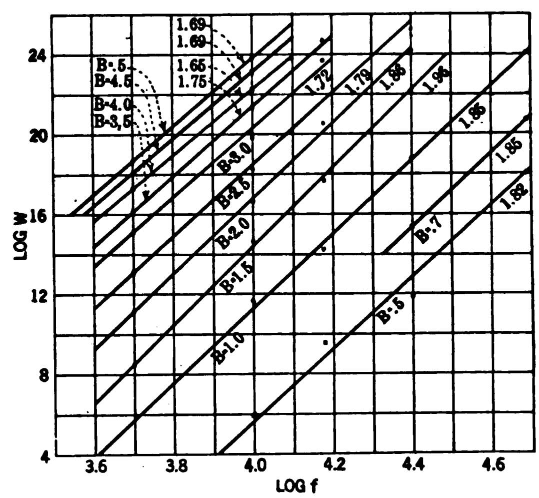


FIG. 9

mentioned above, and a similar reasoning may be applied to the changes with induction, since for the range of induction used in these tests the permeability is increasing with the induction and consequently the skin effect is increasing, thus tending to decrease the eddy current losses from what they would be without this increased skin effect.

*See Transient Electrical Phenomena and Oscillations, p. 359.

Accuracy of Results

The results are probably not reliable to better than 5 per cent. One of the principal sources of error was the fact that at some points the test voltage did not remain very constant in spite of frequent adjustment. This was due partly to variations in the d-c. supply and partly to other causes not fully determined. It was necessary to use a generator for supply as no 500-volt battery was available. Another source of error was due to the changes in the temperature of the calorimeters. In one or two instances these temperatures rose as high as 50 deg. cent. This would of course produce decreased eddy current losses due to the increased resistance of the material. This effect was comparatively small, however, as 4 per cent silicon steel has a fairly low temperature coefficient of resistance. The temperatures were recorded and corrections can be made at a later date if desired. At the lower frequencies the readings of the wave meter were not as sharp as might have been desired due to the fact that the meter was constructed from apparatus that happened to be available and was not as suitable as we might have wished. Another possible cause of error was the fact that while exciting current was probaly very nearly a sine wave the voltage due to the variations in the permeability of the sample with induction undoubtedly contained some harmonics. The inductions were calculated assuming a sine wave of voltage. The errors introduced due to this cause should be small, however, since the samples were not tested at high inductions where such distortions are very appreciable, and also because the instantaneous induction was not uniform.

Conclusions

A method of making high-frequency iron loss tests has been presented which is satisfactory for the range of frequencies used, namely 5000 to 50,000 cycles per second and which without material alterations could be used up to at least a million cycles.

Data are presented showing the iron losses for five-mil silicon steel. An approximate separation of hysteresis and eddy current losses has been made showing the result of skin effect on these losses.

From these data it should be possible to predict more accurately the results obtainable with other gages of material for high-frequency work than was possible with previous obtainable data or formulas.

Electric Power Consumption on the Electrified Rocky Mountain and Missoula Divisions of the Chicago, Milwaukee, & St. Paul Railway

By REINIER BEEUWKES

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POWER for the electrical operation of the Chicago, Milwaukee & St. Paul Railway, between Harlowton, Mont. and Avery, Ida., is delivered to the transmission system of the Railway in the form of 100,000-volt, three-phase, 60-cycle current. The power is supplied under two separate contracts, one for the Rocky Mountain Division, extending from Harlowton to Deer Lodge, and the other for the Missoula Division, extending from Deer Lodge to Avery.

The Power Company's 100,000-volt transmission system is shown in Fig. 1, as are also the points of power delivery to the Railway Company and the latter's 100,000-volt transmission system. The Railway transmission line of the Rocky Mountain Division extends from Two Dot substation to the Morel substation, a distance of 184 miles, the former point being 12 miles from Harlowton, the eastern terminus of the Division, and the latter point 17 miles from Deer Lodge, the western terminus. Power is delivered by the Power Company at the Two Dot, Josephine, Piedmont, Janney and Morel substations. The Railway transmission line of the Missoula Division extends from Gold Creek substation, 18½ miles from Deer Lodge, a distance of 180 miles, to the substation at Avery, the western terminus of the Division.

Seven substations on each Division are used to convert the 100,000-volt alternating current of the transmission line to the 3000-volt direct current used for traction purposes. Each motor-generator consists of two 1500-volt direct-current generators connected in series and driven by a 2300-volt synchronous motor supplied from the substation high-tension buses through a three-phase, 100,000/2300-volt transformer and is guaranteed for a maximum five-minute overload of 200 per cent. The rated capacities of these stations are as follows:

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Substations	Transformers	Motor-generators
Rocky Mountain Division		
Two Dot	2—2500 kv-a.	2—2000 kw.
Loweth	2—2500 "	2—2000 "
Josephine	2—2500 "	2—2000 "
Eustis	2—2500 "	2—2000 "
Piedmont	3—1900 "	3—1500 "
Janney	3—1900 "	3—1500 "
Morel	2—2500 "	2—2000 "
Missoula Division		
Gold Creek	2—2500 kv-a.	2—2000 kw.
Ravenna	2—2500 "	2—2000 "
Primrose	2—2500 "	2—2000 "
Tarkio	2—2500 "	2—2000 "
Drexel	2—2500 "	2—2000 "
East Portal	3—2500 "	3—2000 "
Avery	3—1900 "	3—1500 "

the trolley in front of each substation separating the trolley system west of the substation from that east of the substation, that is, portions east and west of the substations are fed, respectively, through separate feeder breakers. There is also an insulated air gap at the beginning and end of every passing track, so that by means of a section switch installed in the feeder at the gap the district between any two gaps may be isolated in case of trouble so as to permit operation up to the location of the open switches.

The return circuit consists of the 90-lb. running rails and, in general, of a No. 0000 B. & S. copper supplementary negative wire which is run along the

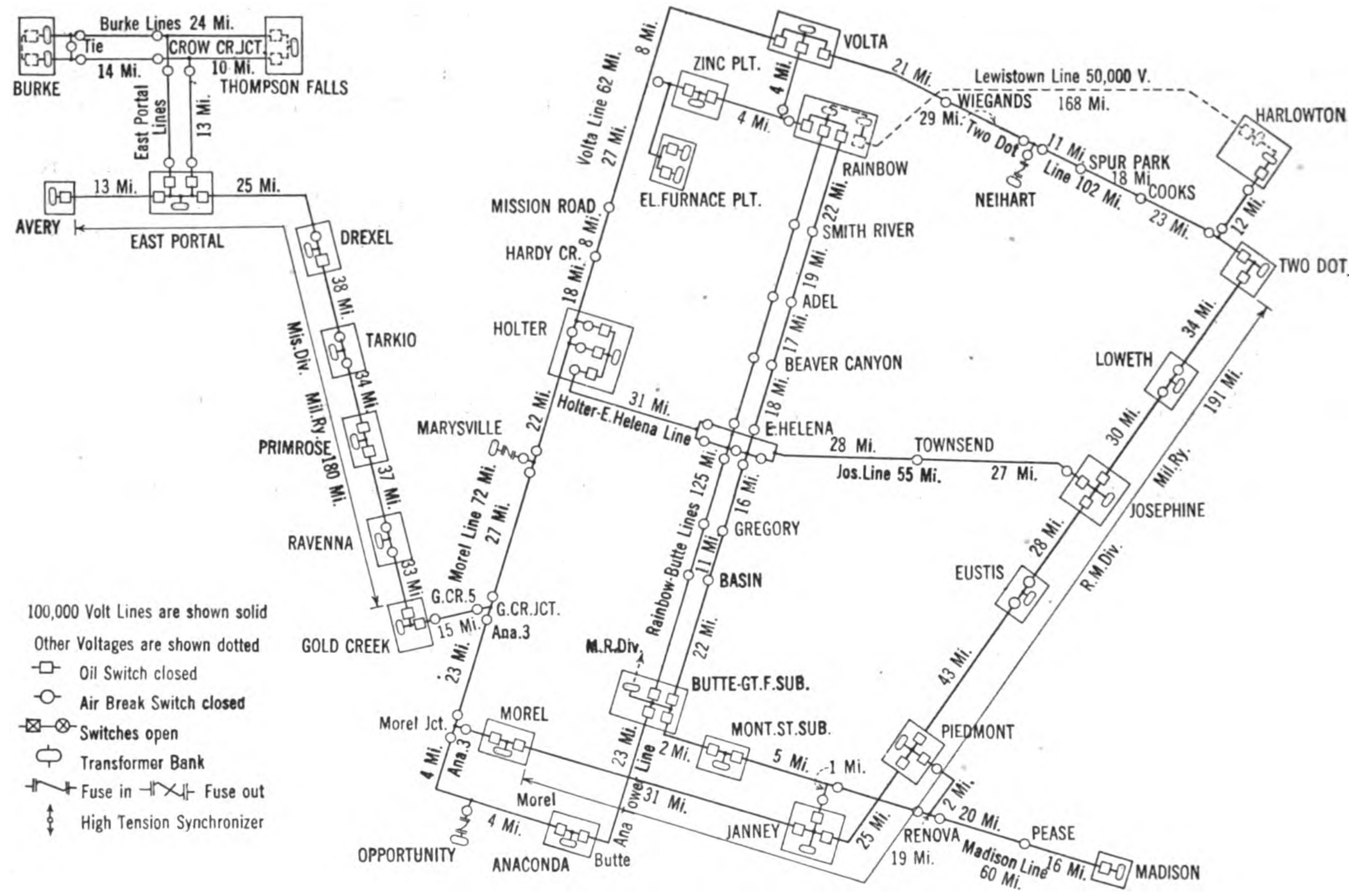


FIG. 1—THE MONTANA POWER COMPANY 100,000-VOLT SYSTEM

The Railway Company's high-tension line, arrangement of apparatus in the substations and the general layout of the 3000-volt distribution or trolley system are shown diagramatically in Figs. 2 and 3.

The contact wires of the trolley system consist for the main line of two No. 0000 B. & S. grooved trolley wires flexibly supported side by side from a ½-in. steel catenary and tapped at intervals of about every thousand feet to a feeder or feeders which connect to the adjacent substation buses through switches and automatic circuit breakers. Over passing, industrial and similar tracks only a single No. 0000 copper trolley wire is used. There is an insulated air gap in trolley poles and connected to the track at intervals averaging about 8000 ft. through each alternate signal system reactance bond. This supplementary negative, however, is intended more as a safety measure to bridge open rail bonds than to increase the return circuit conductivity. However, on various feeder cut-offs on the mountain grades, where the conductivity of the positive circuit closely approaches that of the return circuit, one of the two feeders on the cut-off is in parallel with the running rails and is provided for the purpose of increasing the return circuit conductivity.

The terms of the power contracts are similar and

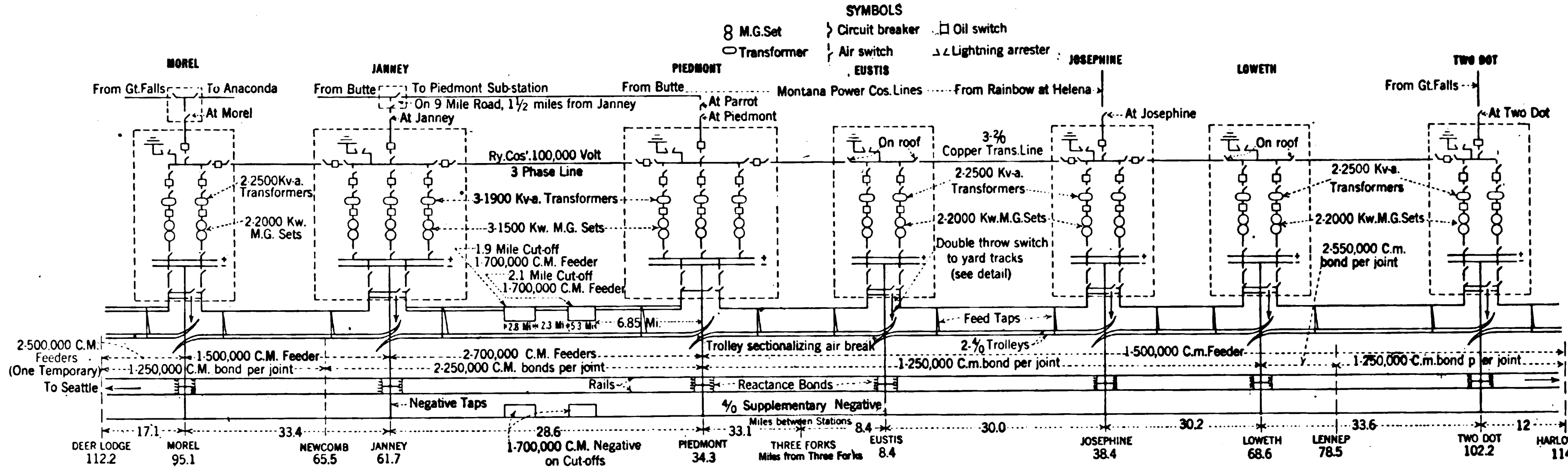
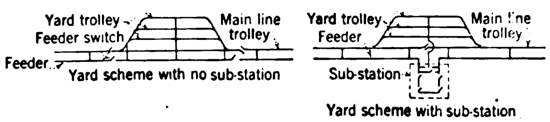


Fig. 2—Transmission and Distribution System—Harlowton to Deer Lodge



Yard Schemes

Feeder and trolley sectionalized at all substations and Railway stations.
One No. 0000 feeder tap to each trolley every 1000 feet.
Reactance bonds 5000 to 6000 feet apart.
Negative-tapped to middle point of every second reactance bond.
Side track rails are bonded in series with the supplementary negative.

One rail bonded with one 250,000 cir. mil bond per joint in yards.
Signal: Two No. 4 B. & S. copper wires carried on trolley poles. Fed both directions from substations, 4400 volts a-c.
Power limiting: Two No. 8 B. & S. copper wires carried on trolley poles—Morel to Two Dot—1200 volts d-c.

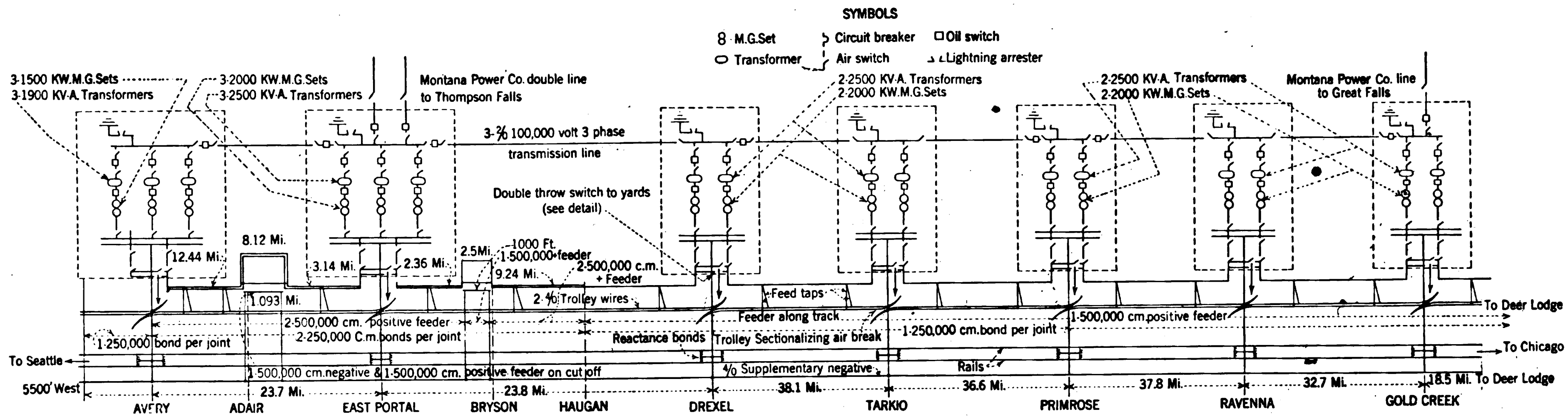


Fig. 3—Transmission and Distribution System—Deer Lodge to Avery

Feeder and trolley sectionalized at all substations and Railway stations.
One No. 0000 feeder tap to each trolley every 1000 feet.
Reactance bonds 5000 to 6000 feet apart.
Negative tapped to middle point of every second reactance bond.
Side track rails are bonded in series with the supplementary negative.
One rail bonded with one 250,000 cir. mil bond per joint in yards.

Trolley feed taps are disconnected for a distance of one mile each side of each substation where there is a single feeder and two miles where there is double feeder, except at Ravenna where the tunnel entrance East, and at East Portal where the tunnel entrance West will limit the distance.

Yard switch at substation left open. Yard trolley at substation connected to main line trolley of east end of yards.

each provides for a minimum payment on basis of a 60 per cent load factor. Where the load factor exceeds 60 per cent, payment is made on basis of the actual kw-hr. consumed, the rate being 5.36 mils per kw-hr. The demand is controlled for each division by means of a so-called Power Indicating and Limiting system, which was put into operation on the Rocky Mountain Division early in the year 1918 and on the Missoula Division a few months ago. Briefly, this system, which was described in detail in the April, 1920 issue of the *General Electric Review*, is so arranged as to indicate and record at the dispatcher's office at Deer Lodge the total kilowatts or demand being latter matter, except as regards passenger trains and certain time freights, being to a considerable extent in the hands of the train dispatchers. The slowing up of the train speeds of course results in increased train and enginemen's expense and increased time in getting freight over the road, and a proper balance must be struck between this increased expense and the saving in power cost, determining upon the limit setting accordingly. The following tabulation will give an idea of the percentage of time the limiting action takes place with average kw. load and settings as indicated, this percentage being based on the number of hours the limiting system was actually in service.

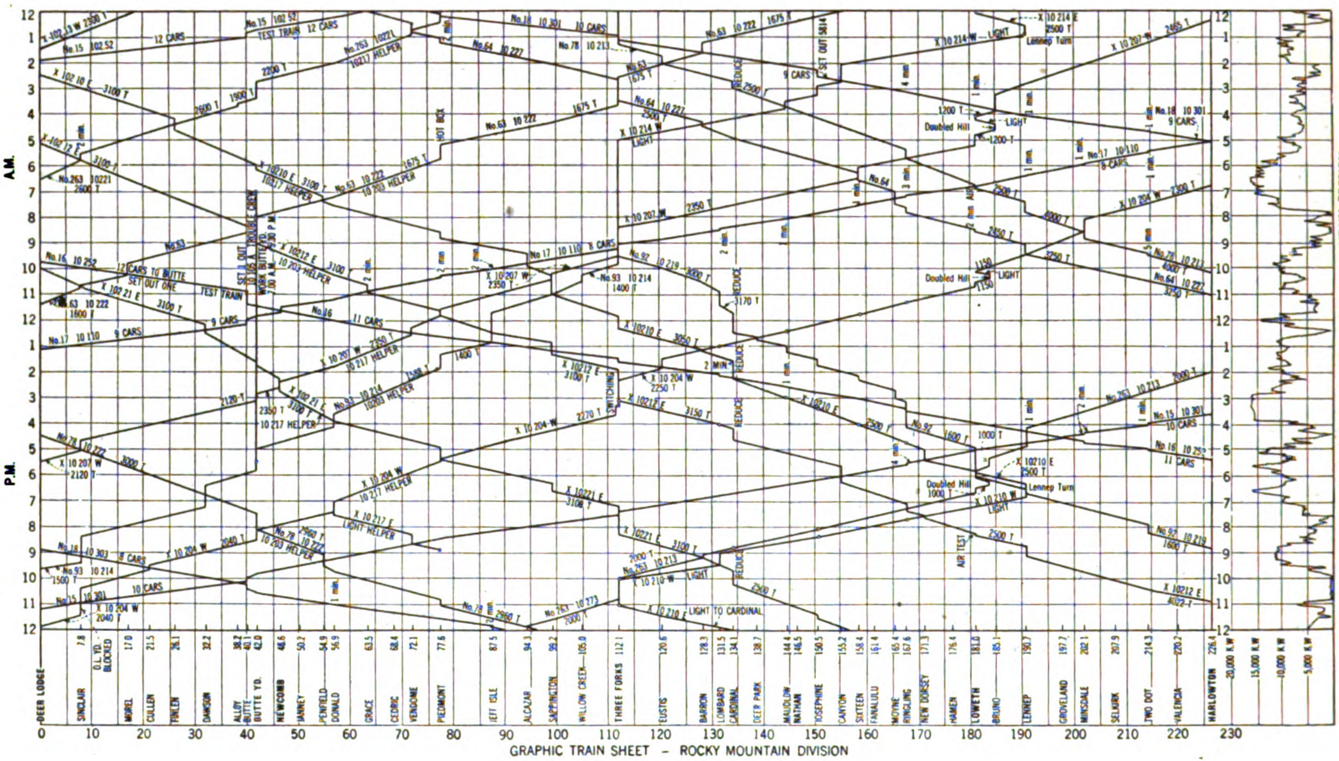


FIG. 4

supplied in any instant by the Power Company to the Railway Company, and to prevent the maximum demand from exceeding a certain amount as determined by the "demand setting made by the dispatcher," this limiting action being secured by lowering of the substation d-c. voltage and therefore of the train speeds.

The effect of this limiting action is clearly indicated in Fig. 4, which shows a graphic time table of train movements on the Rocky Mountain Division for February 19, 1920 and corresponding load curve traced by tapalog meter of the Power Indicating and Limiting system with the load limit set at 16,000 kw.

The percentage of time when the limiting action will take place will, for a given amount of business, depend on the demand setting and on the possibilities of spacing the trains so that as few as possible will at one time be operating on the heavier grades; the

Month	Limit setting	Avg. monthly kw. actual	Per cent time limiting actual takes place
July, 1918	12,000	8,020	13.0
Aug., "	12,000	7,820	15.5
Sept., "	12,000	6,675	8.2
May, 1919	14,000	7,840	4.62
Aug., "	14,000	7,650	4.12
Sept., "	14,000	8,230	9.50
Oct., "	14,000	8,420	10.65
Nov., "	14,000	7,115	8.24
Feb., 1920	16,000	8,625	2.40
Mar., "	16,000	8,680	2.20
Apr., "	16,000	8,620	1.90

In arriving at the amounts chargeable for power against the different respective classes of train service, the total kw-hr. to be paid for, that is, the actual kw-hr., or same increased, if necessary, to correspond to a minimum 60 per cent load factor, is taken and from it

is deducted the kw-hr. metered against substation lighting, auxiliary power, signal system supply, etc. amounting to about 1 per cent. The remaining kw-hr. is then split against the different classes of train service, freight, passenger and non-revenue, in proportion to the total net kw-hr. readings obtained for these respective services from wattmeters installed in the locomotives. These readings are taken by the engine crew on entering and leaving the engine on a form provided for the purpose, and a record of the power consumption of each train is thus obtained. The readings are referred to as "net" readings, as they represent motored energy less regenerated energy.

The ratio of the total net locomotive wattmeter readings, all services, to the total actual kw-hr. input to system chargeable to locomotives for the various months of 1919 and for the whole year is given below:

	ROCKY MOUNTAIN DIV.			MISSOULA DIV.		
Month	Actual kw-hr. system input for locos.	Net kw-hr. input at locos.	Ratio	Actual kw-hr. system input for locos.	Net kw-hr. input at locos.	Ratio
Jan.......	6,381,233	4,838,480	75.9	5,540,581	3,753,430	67.6
Feb.......	4,610,607	2,921,840	63.3	4,107,960	2,702,710	65.8
Mar.......	5,795,859	4,351,126	75.2	5,412,048	3,469,120	64.2
Apr.......	5,949,840	3,962,650	66.6	5,429,932	3,574,080	65.8
May......	5,803,455	4,146,517	71.4	5,745,397	3,795,770	66.2
June......	5,662,650	4,100,810	72.3	5,697,785	3,853,590	67.6
July......	5,744,738	3,794,940	66.2	5,318,692	3,505,630	65.8
Aug.......	5,648,815	3,755,280	66.5	5,133,008	3,255,820	63.4
Sept.	5,892,430	3,799,830	64.5	5,102,562	3,434,010	67.3
Oct.......	6,222,486	3,971,149	63.8	5,389,883	3,654,955	67.8
Nov.......	5,095,937	3,425,458	67.2	4,879,130	3,181,456	65.2
Dec.......	5,809,976	3,830,870	65.8	4,971,601	3,382,700	67.9
	68,618,026	46,898,950	68.3	62,728,579	41,563,271	66.3

As there are no wattmeters installed in the direct-current side of the substations, a ratio for net substation output to system input or to locomotive input is not obtainable. There are, however, wattmeters in the circuits of the individual motor-generator sets, and the following table considered in connection with Profile, Fig. 5, will be of interest in showing the manner in which the energy is distributed among the respective substations, average kw. being used for convenience instead of total kw-hr., and the whole of the year 1919 being taken.

ROCKY MOUNTAIN DIVISION			MISSOULA DIVISION		
Substation	Avg. annual kw. input net to motor-genrs. *Total	†Per motor-gen.	Substation	Avg. annual kw. input net to motor-genrs. *Total	†Per motor-gen.
Two Dot..........	895	813	Gold Creek	1150	1128
Loweth...........	962	783	Ravenna	915	1115
Josephine.........	1014	1013	Primrose	908	925
Eustis............	1022	1016	Tarkio	843	803
Piedmont.........	1218	617	Drexel	790	778
Janney...........	1390	559	East Portal	1390	778
Morel............	1047	1072	Avery	812	523
System Total......	7548		System Total	6808	

*Total Kw-Hr.—Hr. in year: 8856 hr. being taken, as four days in December are included.

†Total Kw-Hr.—Total running hr. of motor-generators.

The figures below show for the year 1919 the net kilowatt-hours per thousand gross ton miles for freight revenue service and passenger service, respectively, and corresponding cost of these kilowatt-hours at tho high-tension bus or point of delivery of the power te the railway system. The lesser consumption of energy during the summer months as compared with the winter months will be noted. The figures for the passenger service are approximate, as the ton mile data are based on the assumption of an average weight per car, no record of the particular cars handled in all the separate trains being available:

Month	Thousands gross ton miles trailing	Net kw-hr. per thousand gross ton miles: Trailing, At high tension bus	Trailing, At locomotive	Train, At high tension bus	Train, At locomotive	load factor	Cost kw-hr. per thous. trailing gross ton mi., cts.
Freight	Service						
ROCKY MOUNTAIN DIVISION							
Jan.......	98,478	47.8	36.3	41.2	31.3	63.7	25.7
Feb.......	79,859	43.1	27.3	37.3	23.6	57.7	24.0
Mar.......	118,297	39.0	29.3	33.9	25.5	65.3	20.9
Apr.......	121,646	38.5	25.6	33.1	22.0	61.1	20.7
May......	124,395	36.5	26.1	31.7	22.6	56.0	20.9
June......	122,264	36.7	26.2	31.7	22.9	56.4	20.9
July	120,723	36.7	24.3	31.6	20.9	55.4	21.3
Aug.......	111,092	40.9	27.2	34.9	23.2	54.6	22.4
Sept.......	115,787	39.7	25.6	34.1	22.0	58.8	21.7
Oct........	108,920	45.8	29.2	39.4	25.1	60.0	23.6
Nov.......	86,267	44.0	29.6	37.7	25.3	50.9	27.8
Jan.—Nov.	Avgs.	40.5	27.7	34.8	23.8	57.3	22.5
MISSOULA DIVISION							
Jan.......	87,598	44.3	29.9	38.6	26.1	....	23.8
Feb.......	73,481	39.8	26.2	35.2	23.2	....	21.7
Mar.......	103,613	40.3	25.8	35.6	22.8	....	21.6
Apr.......	109,133	38.5	25.4	34.1	22.4	....	20.2
May......	118,331	37.9	25.1	33.5	22.2	....	20.3
June......	116,660	37.8	25.6	33.3	22.5	....	20.3
July	106,045	38.1	25.0	33.5	22.0	....	20.4
Aug.......	101,017	38.8	24.6	34.3	21.8	....	20.8
Sept.......	99,578	38.5	25.9	34.1	22.9	....	20.6
Oct........	100,504	40.0	27.1	35.3	23.9	....	21.4
Nov.......	78,459	45.3	29.5	39.2	25.5	....	24.3
Jan.—Nov.	Avgs.	39.7	26.3	35.0	23.1	....	21.3
ROCKY MOUNTAIN AND MISSOULA DIVISIONS COMBINED							
Jan.—Nov.	2,302,507	40.1	27.1	34.9	23.5	....	21.9
Jan.—Dec.	2,476,085	....	....	....	....	....	22.3
Passenger S	ervice						
Jan.—Nov.	340,480	56.8	38.7	39.7	27.1	....	38.4
Jan.—Dec.	378,080	....	....	....	....	....	38.1

The cost of maintaining and operating the transmission lines, substations, and trolley system, for the year 1919 is given below and a final figure thus arrived at showing the approximate total operating costs involved in the delivery of the electric energy to the locomotives.

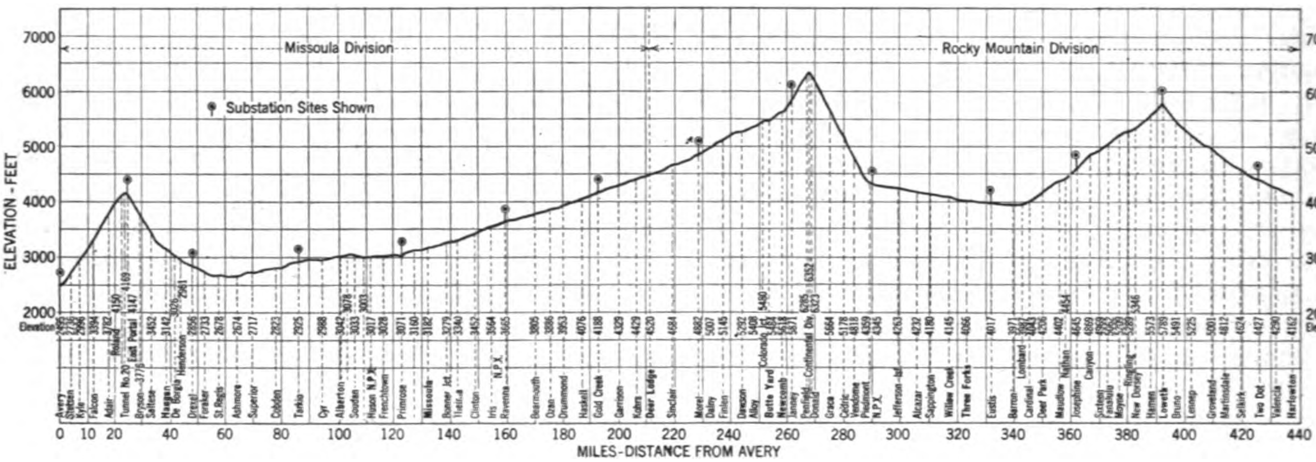


Fig. 5—Profile—C., M. & St. P. Ry.—Missoula and Rocky Mountain Divisions

Account	Total All Services	Per Unit
255. Power Substation Bldgs...	$8,487	$606.00 per Bldg.
257. Power Transmission System..................	1,773	4.87 " mi.
259. Power Distribution System..................	78,461	179.00 " route mi.
261. Power Line Poles & Fixtures.................	24,299	55.50 " " "
306. Power Substation Apparatus.................	40,224	2870.00 " station
383. } Train and Yard Power 935. } Produced.............	102,152	7300.00 " "
Total...................	$255,396	

1. Cost per Thousands Gross Ton Miles trailing freight as actually distributed in accounts	28.8c
2. Cost per Thousands Gross Ton Miles train freight as actually distributed in accounts..	24.9c
3. Cost per Thousands Gross Ton Miles trailing freight on basis distribution in proportion to freight kw-hr......................	30.2c
4. Cost per Thousands Gross Ton Miles train freight on basis distribution in proportion to freight kw-hr......................	26.2c
5. Cost per actual kw-hr. delivered to locomotives............	1.1c

The above unit figures include the cost of power.

The installation being comparatively new it might naturally be assumed without consideration of other facts that the figures for the maintenance are considerably lower than those which will eventually obtain, but it should also be borne in mind that the maintenance and operating costs given will, except for power, remain more or less constant as far as any consideration of their being affected by the business handled is concerned, so that the cost per thousand ton miles would be correspondingly reduced as business is increased. It is also expected that considerable improvement will be effected in maintenance methods which would again tend to reduce costs. The figures are therefore given merely to show the results which are at present being obtained.

AMERICAN PAPER NOW USED ENTIRELY BY TELEPHONE MANUFACTURERS

The newspaper trade is not the only industry which is being affected by the shortage of paper. Few users of the telephone realize that one of the big elements in the makeup of the underground cable, the magneto and several of the other important adjuncts to the lines of communication is paper. In fact, it is the big factor for insulating purposes. Several layers of it are used beneath the leaden sheath the average human sees when telephone cables are being laid in the streets of his vicinity. The shortage condition of the grade of paper which has always been used has become so acute that several experts of the Western Electric Company are devoting all their efforts to developing some type of substitute.

Manila pulp paper has always been the big favorite among telephone cable manufacturers. Recently wood pulp has been used because of the shortage of the former but it still lacks several of the finer qualities of the imported grades. Elasticity and a non-porous condition are absolutely necessary.

Prior to the war large quantities of all-linen paper made in Europe were used in certain processes in making condensers. None of the American manufacturers cared to handle it as it required so much attention and had such a limited distribution. However, three companies have now taken over the task in this country and although cotton is used to a large extent their output is every bit as good as that of their foreign competitors.

AERIAL MAPPING

The Army Air Service is now cooperating with map-making companies in making detailed maps of the immediate vicinity of Washington. This is another step in proving the reliability and utility of maps made from the air for commercial work. A number of very successful and complete air maps have been made in the past and following the success of each venture larger projects are undertaken in map-making from the air. Important camera developments are now having the attention of the Air Service for this work, together with other special airship equipment.

Some cooperation has been given to the Coast & Geodetic Survey and it is contemplated that aerial photography will eventually be a considerable help in developing the complete topographic map of the States.

The Electric Dynamometer Test of the Pierce Arrow Engine

By KARR PARKER
Engineering Manager, McCarthy Bros. & Ford

THE electric dynamometer is now generally recognized as the standard equipment for testing automobile engines. Dynamometers are used not only to measure the power of the engine in the final test but also are employed as tools in the production of the engine. Engines when first assembled are "run in" on block test dynamometers until the bearings, etc., are worked in. In this process the dynamometer runs as a motor delivering power to the engine. When the friction load on the engine has been reduced to the proper value as determined by a meter on the dynamometer control panel, the engine is fired and drives the dynamometer as a generator returning current to an absorption resistance or to the plant system, thus providing a load for the engine. The engine is tested for power one with this artificial load.

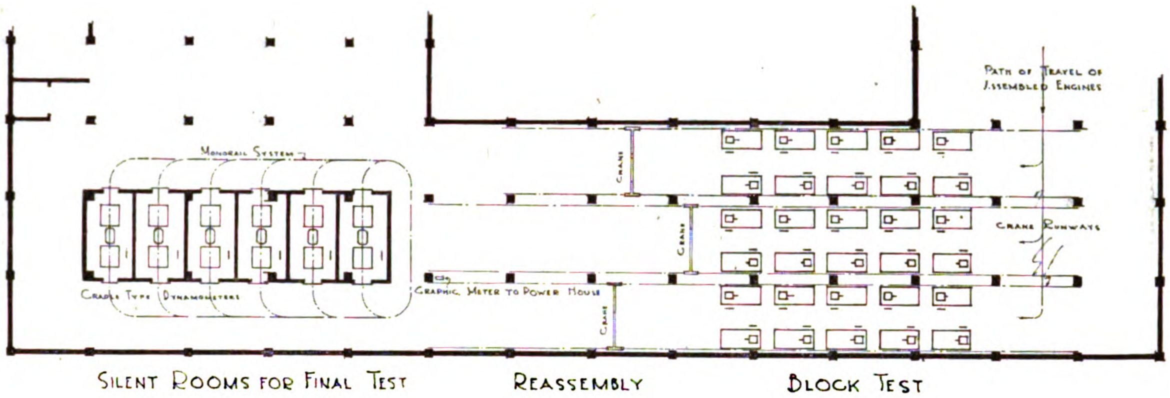


FIG. 1

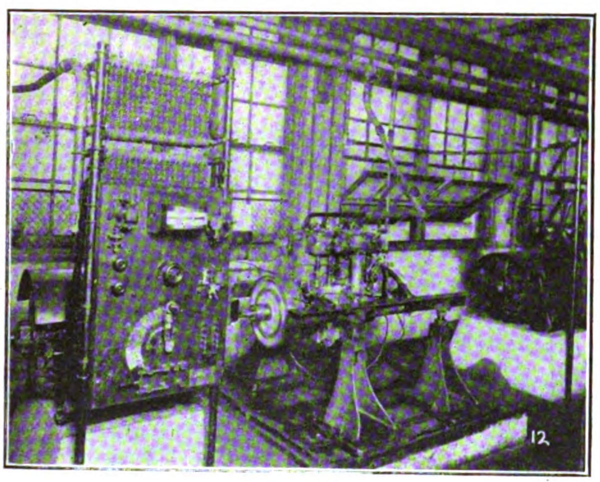


FIG. 2

A complete dynamometer testing equipment has recently been installed at the plant of the Pierce Arrow Motor Car Company. The engine test here is exceptionally rigid and the installation is considered to be one of the best in existence.

The old method of testing this engine consisted in "running in" the engine by belting to a line shaft. This process required a number of hours and was a fixed period for each engine. The engine was then transferred to a test room and coupled to a fan. It was then fired and run at various speeds over a fixed schedule for some days. The fan provided the artificial load and the power developed was calculated from the fan characteristics.

In designing the electric dynamometer installation careful attention was paid to locating the equipment so that the engine would not only receive proper test but would also pass from production to test directly without delay. The testing floor plan is shown in Fig. 1. Engines when finished are transferred to the block test stand by means of an electric hoist and are "run in" until their friction load drops to a predetermined value. The dynamometer runs as a motor at this stage of the process taking current from the test room bus which is supplied by other dynamometers which are generating. A block test unit in operation is shown in Fig. 2. The meter on the panel reads directly in horse power and kw., the efficiency of the dynamometer having been taken account of in the calibration of the instrument. The engine is then fired and run for several hours at various speeds and powers as called for by the test schedule.

The power generated during the process is 250-volt direct current. The surplus power is transmitted to

the power house; changed into three-phase, 25-cycle, 440-volt alternating current by a 550-kw. synchronous converter and is then used to drive various a-c. motors in the factory. The synchronous converter switchboard is shown in Fig. 3. A surplus of several hundred horse power is available from the dynamometer test

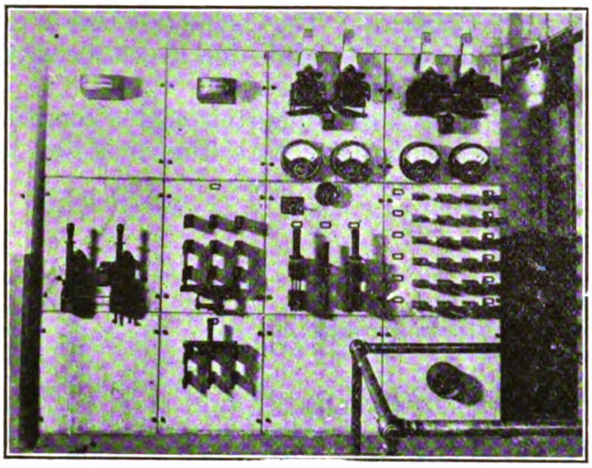


FIG. 3

at all times. Testing is arranged on a uniform schedule which gives a certain number of engines firing at all times. A view of the block test section of the testing room, showing overhead cranes, is shown in Fig. 4. A total of 30 units is installed here.

If an engine gives trouble in the block test or fails to come up to power it is immediately rejected and

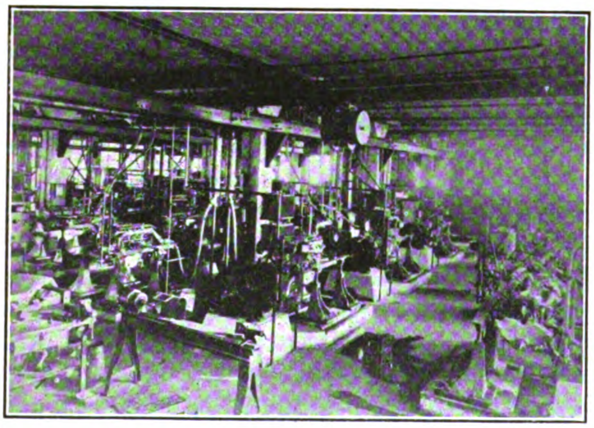


FIG. 4

sent back to be taken down. After an engine passes the block test it is taken down for careful examination, reassembled and delivered by means of an electric monorail hoist to the final test. Fig. 5 shows a passenger car engine being delivered to one of the "silent rooms" for final test.

The final test is conducted on a cradle type dynamometer of 150-h. p. capacity capable of running at speeds up to 3500 rev. per min. This machine consists of a special direct-current interpole generator mounted on ball bearing pedestals so that the entire frame of the machine is free to turn. When the machine is operating the field tends to turn with the armature but is restrained by means of a scale and lever

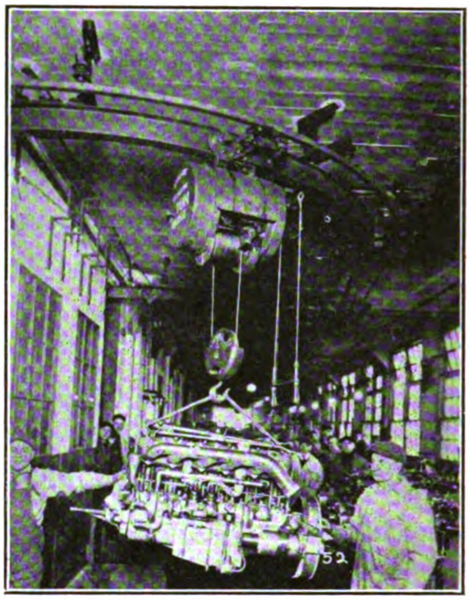


FIG. 5

mechanism with limit stops. The torque exerted on the field by the revolving armature is read on this scale; the speed is read from an electric tachometer.

The power is,

$$\text{h. p.} = \frac{2\,\pi.\ \text{rev. per min. . lb. pull . torque arm}}{33{,}000}$$

This is worked out on a chart so that the tester can read h. p. directly from the line on the chart without calculation.

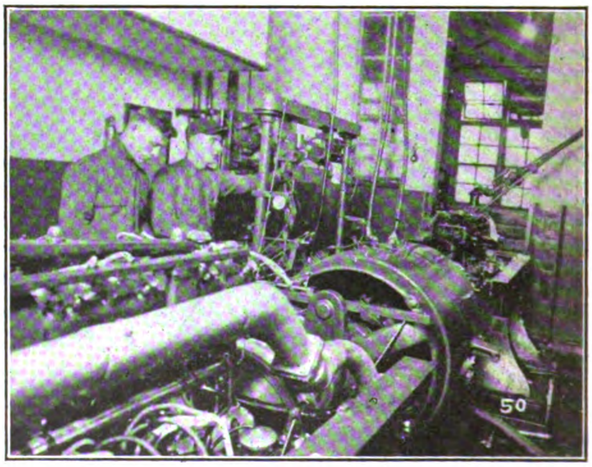


FIG. 6

The cradle dynamometer is arranged with a double extended shaft with heavy bed plate and adjustable engine supports on each end. Considerable time is required to set up an engine, attach flexible coupling,

water, gasoline and oil piping, and line up with the dynamometer shaft. With this double ended arrangement an engine can be set up on one end while another engine is being tested, thus reducing the idle time of the dynamometer to a minimum. A passenger engine undergoing final test is shown in Fig. 6.

The final test is conducted in sound-proof rooms, each engine being tested in a room by itself so as to detect knocks and noises which indicate engine trouble. A power curve is taken of each engine.

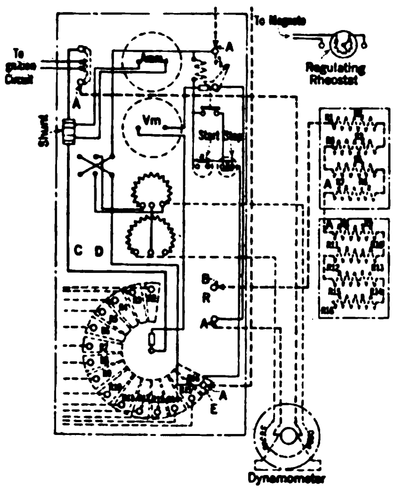


FIG. 7—WIRING DIAGRAM OF DYNAMOMETER PANEL

The control system on the cradle dynamometers is shown in Fig. 7. A wide range of speed in several thousand steps from 0—3500 rev. per min. can be obtained by combined armature and field control. An automatic circuit breaker provides overload protection. This breaker has an auxiliary switch which cuts out the engine ignition when the breaker opens thus preventing the engine from running away. Automatic control is used with control buttons located at tester's desk where the engine controls are also placed. Dynamometer fields are separately excited and when the dynamometer is generating above bus voltage of 250 volts at high speeds, the load is absorbed on a grid resistance.

The principal advantages which the electric dynamometer test has shown over the old method in this plant may be summarized as follows:

a. A more accurate and thorough test.

b. The ability to measure each engine individually and to give a motor individual treatment.

c. Shortening the average test period.

d. Motor rejections on road tests practically eliminated.

e. Increased production because of better arrangement of test room.

f. Defective motors promptly detected.

g. Several hundred horse power formerly wasted is now utilized.

TESTS ON FADING RADIO SIGNALS

Simultaneous nightly tests by 50 radio stations on the fading of radio signals were conducted from June 1 to July 17. The tests covered the northeast quarter of the United States. One thousand records of signal intensity variation have been secured.

A conference has been held to review the results and plan further work by representatives of the Radio Laboratory of the Bureau of Standards, the Naval Air Service, the Department of Terrestrial Magnetism of Carnegie Institution of Washington, and the American Radio Relay League. The data secured are being analyzed. A revised arrangement of cooperating stations will be utilized in future tests, which it is planned to run in October, January and April respectively.

Like the former tests these will be run between 10 and 11 p. m., eastern standard time, and at a wave length of 250 meters. It is intended also to make noonday and sunset runs.

The operation of the first test series has been satisfactory, 60 per cent of the possible number of reports having been secured over an average transmission distance of 350 miles. This is an excellent record for an undertaking in which the observing work is done on a voluntary basis. The power input at the transmitter did not exceed one kilowatt in any case.

One of the six transmitters was a 500-cycle quenched-gap set, two were 60-cycle non-synchronous rotary gap sets, and two were continuous-wave sets using electron tubes. All receiving stations were equipped with regenerative electron-tube receiving sets of the tuned plate-circuit type.

AN ELECTRON TUBE TRANSMITTER OF COMPLETELY MODULATED WAVES

The Bureau of Standards has recently issued Scientific Paper No. 381 on the above subject.

In order to utilize a radio-frequency wave train of given power most effectively in a non-oscillating receiving system it must be completely modulated, at some suitable audio frequency. A convenient way of accomplishing this modulation, when an electron tube generator is used, is by supplying the plate circuit of the tube or tubes with an audio-frequency alternating e. m. f. An alternator may be used with suitable transformers to supply both the filament and plate circuits. A self-contained transmitting set of this type has been designed and built at the Bureau of Standards. A description of the set, with illustration and diagrams is given. Over-all efficiency as high as 35 per cent is obtained with the set. Transmission and reception tests are described, in which the waves were received by heterodyne methods and also with a crystal detector.

This paper is now ready for distribution and anyone interested can obtain a copy by addressing the Bureau of Standards.

External Field Produced by a Cylindrical Electromagnet

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AND
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IN some investigations by the authors during the Great War occasion arose to solve the following problems:

PROBLEM A. Given the dimensions and permeability of a straight cylindrical iron core, how many ampere-turns, uniformly distributed over the length of the core, are required to produce a given magnetizing force (magnetic field intensity) at a point on the axis of the core at a distance from its center large in comparison with its length?

Answer:

$$\text{Ampere-turns} = \frac{6.37\,x^3}{d^2}\left(\frac{1}{\mu} + \frac{K}{\rho^2}\right)H$$

where

H = magnetizing force, in gilberts per cm.,
x = distance of point from center of core, in centimeters,
d = diameter of core, in centimeters,
μ = average permeability of core, in c. g. s. electromagnetic units,
ρ = ratio of the length of the core to its diameter,
K = a factor whose value depends upon the value of ρ, and given by the lower curve in Fig. 6.

PROBLEM B. When the core is excited by means of an alternating current, how many volt-amperes are required to produce a given maximum magnetizing force at a point on the axis of the core at a distance from its center large in comparison with its length?

Answer:

$$\text{Volt-amperes} = \frac{\pi^2 f\,x^6}{V}\left(\frac{1}{\mu} + \frac{K}{\rho^2}\right)H^2 \times 10^{-7}$$

where

f = frequency of current, in cycles per second,
V = volume of core in cubic centimeters

and other symbols as in Problem A.

PROBLEM C. What disposition of the winding on the core will require the least number of volt-amperes for a given magnetizing force at the given point; *i. e.*, should the winding be uniform, concentrated at the center of the core, or concentrated at the ends?

Answer: For maximum external field per volt-ampere of excitation, the winding should cover the entire length of core and be uniformly distributed.

PROBLEM D. For a given number of volt-amperes, and given weight of core, by how much will the magnetizing force at a given point on its axis (extended) be increased by using a tapered core (*e. g.*, cone-shaped ends) instead of a core of uniform cross-section?

Answer: For the same volume of core and same number of ampere-turns, a tapered core will give a slightly greater magnetizing force, but the difference is so small that it is doubtful whether the slight gain from a tapered core would justify the extra cost.

The method of arriving at the above conclusions is given in detail in the following paragraphs.

MAGNETIZING FORCE AT EXTERNAL POINT ON AXIS OF CORE EXPRESSED IN TERMS OF THE AVERAGE FLUX IN THE CORE

The strength of the magnetic pole at an area $d\,S$ of the surface of a piece of iron or other magnetic substance (the surrounding medium being non-magnetic) is

$$d\,m = \frac{d\,\phi}{4\,\pi}(1 - 1/\mu) \tag{1}$$

where $d\,\phi$ is the magnetic flux (number of lines of magnetic force) through this area and μ is the permeability of the iron just inside this surface.[1] In this formula all quantities are in c. g. s. electromagnetic units. When the permeability is 100 or more c. g. s. electromagnetic units, equation (1) becomes, with an error of less than 1 per cent,

$$d\,m = \frac{d\,\phi}{4\,\pi} \tag{1 a}$$

The magnetizing force (or magnetic field intensity) at any point P at a distance x from a pole of strength $d\,m$, due directly to this pole, is, in c. g. s. electromagnetic units,

$$d\,H = \frac{d\,m}{x^2} \tag{2}$$

irrespective of the nature of the medium in which the point P is located. Hence, at a point P at a distance x from an area $d\,S$ in the surface of a magnet, through which area passes $d\,\phi$ lines of force, the magnetic pole at this area produces a magnetizing force

$$d\,H = \frac{d\,\phi}{4\,\pi\,x^2} \tag{3}$$

The magnetic poles on a straight iron core, even

1. See Pender, Harold, *Electricity and Magnetism for Engineers*, (1918,) p. 241.

though it be relatively long compared with its diameter, are in general not confined to its end surfaces, but are distributed over its lateral walls as well. That is, an appreciable proportion of the total flux through the core passes out through its lateral walls, so that the flux through successive cross-sections of the core diminishes with the distance of the given cross-section from the center of the core, as shown in Fig. 1.

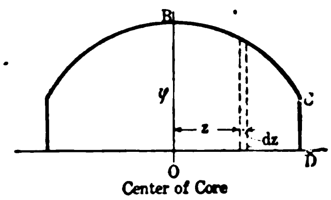

FIG. 1

Consider the special case (Fig. 2) of a point P which is on the axis of a straight core of length l, and at such a distance x from its center that $(l/x)^2$ is negligible in comparison with unity. Consider an elementary length $d\,z$ of this core at a distance z from its center and in its north pole half. Let $d\,\phi$ be the flux which passes through the lateral walls of this elementary

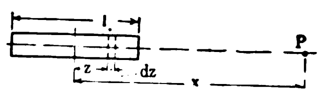

FIG. 2

length, *viz.*, $d\,\phi$ is the difference between the flux through the cross-section which is at a distance z from the center of the core and the flux through the cross-section at the distance $(z + d\,z)$ from the center.

Then the magnetizing force at P due to the pole on the lateral walls of the length $d\,z$ is

$$d\,H_n = \frac{d\,\phi}{4\,\pi\,(x-z)^2} \tag{4}$$

Similarly, the magnetizing force at P due to the pole on the lateral walls of an elementary length $d\,z$ at a distance z from the center of the magnet, but in its south pole half, is

$$d\,H_s = -\frac{d\,\phi}{4\,\pi\,(x+z)^2}$$

The resultant magnetizing force at P d to these two elementary lengths is then

$$d\,H = \frac{d\,\phi}{4\,\pi}\left[\frac{1}{(x-z)^2} - \frac{1}{(x+z)^2}\right]$$

$$= \frac{z\,d\,\phi}{\pi\,a^3\left[1-\left(\frac{z}{x}\right)^2\right]^2} \tag{5}$$

When a is so large in comparison with z that $\left(\frac{z}{x}\right)^2$ may be neglected in comparison with unity, as is here assumed, this equation becomes

$$d\,H = \frac{z\,d\,\phi}{\pi\,x^3} \tag{5a}$$

The resultant magnetizing force at P due to the magnetic poles on the entire lateral surface of the core is the integral of this expression between the limits $z = 0$ and $z = l/2$. Hence the resultant magnetizing force at P due to the poles on the entire surface of the core is (see Fig. 1)

$$H = \frac{1}{\pi\,x^3} \times (\text{Area } B\,C\,D\,O)$$

The area $B\,C\,D\,O$, however, is equal to the *average* value of the flux through the core (*i. e.*, the average ordinate of the curve $B\,C$) multiplied by one-half the length of the core. Let this average flux be designated ϕ_a. Then the resultant magnetizing force at P is

$$H = \frac{l\,\phi_a}{2\,\pi\,x^3} \text{ gilberts per cm.} \tag{6}$$

where l is the length of the core, in centimeters, x is the distance of the point P from the center of the core, in centimeters; and ϕ_a is the average flux through the core in maxwells.[2]

Hence the magnetizing force produced at any point on the axis of a straight core at a distance from its center great in comparison with its length is (1) directly proportional to the length of the core, (2) directly proportional to the *average* flux through the core, and (3) inversely proportional to the cube of the distance of the point from the center of the core.

In order to check this formula, and others which will be given subsequently, an iron core solenoid was constructed as follows: The core was a bundle of 272 straight, soft iron wires. The cross-section of the bundle was practically circular. The length of the core was 102 centimeters. The total cross-section of iron in the core was 8.45 square centimeters. As the "effective" diameter of the core is taken the diameter of a circle of this same radius, *viz.*,

$$d = \sqrt{\frac{4 \times 8.45}{\pi}} = 3.28 \text{ centimeters.}$$

The core was uniformly wound throughout its length (except the last two centimeters at each end) with a total of 735 turns of insulated copper wire (No. 12 A. W. G.). This winding was divided into 21 coils, with both terminals of each coil brought out to binding posts. With this arrangement the core could be excited with any number of coils in series, or different currents could be sent through the several coils in order to make any desired distribution of the ampere-turns.

2. The gilbert per centimeter is the same as the c. g. s. electromagnetic unit of magnetic field intensity.

The flux through the successive cross-sections of the core was measured by means of an exploring coil and ballistic galvanometer. The magnetizing force at a point on the axis of the core, 315 centimeters from its center, was measured by means of a magnetometer.

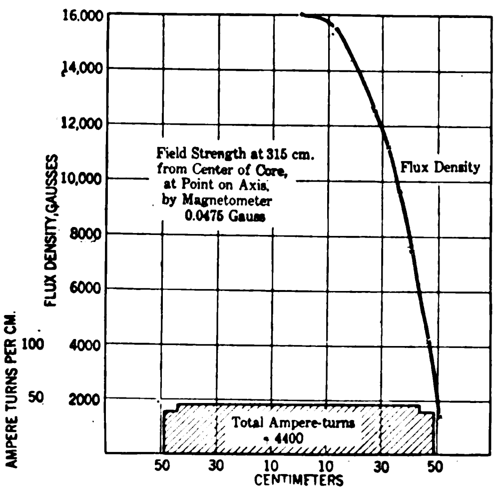

Fig. 3

In Figs. 3, 4 and 5 are shown the flux distribution in the core for three different distributions of the ampere-turns. Fig. 3 shows the flux distribution for a current of 5.98 amperes in the winding when all

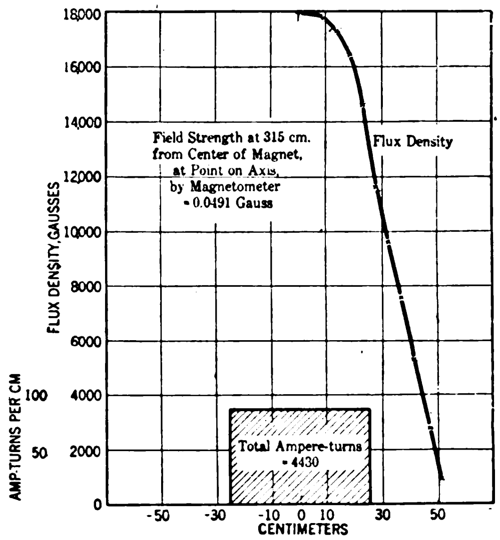

Fig. 4

the coils were connected in series (uniform distribution of ampere-turns). Fig. 4 shows the flux distribution for a current of 11.5 amperes in the 11 coils (total of 385 turns) covering the central half of the core.

Fig. 5 shows the flux distribution when the 21 coils were connected in parallel, with a suitable resistance in series with each, and the currents in these coils adjusted to give practically the same flux through each cross-section of the core. The currents in the coils were as follows:

Coil No.	1&21	2&20	3&19	4&18	5&17	6to 16
Length of coil, cm.	5.3	4.6	4.6	4.6	4.6	4.6
Amperes	51.0	2.70	2.00	1.50	1.10	0.84

The 21 coils were numbered consecutively from one end of the core to the other. The same distribution of ampere-turns would have been obtained from a series winding of 21 coils, had the coils had the following numbers of turns;[3]

Coil No.	1&21	2&20	3&19	4&18	5&17	6&16
Turns per coil	2130	112	83	63	46	35
Turns per cm.	402	24	18	14	10	7.6

The total number of coils in this equivalent winding is 5253, and the equivalent current is 0.84 amperes.

In Table I are given the calculated and observed values of the magnetizing force at a point on the axis of the core 315 centimeters from its center.

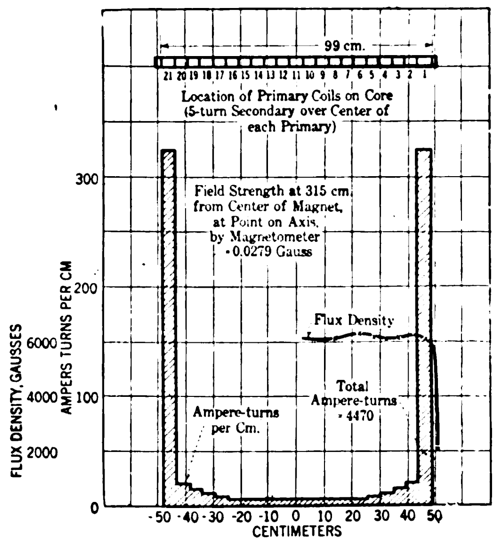

Fig. 5

TABLE I

Flux distribution	Average flux	Magnetizing force	
		Calculated	Observed
Fig. 3	99,000	0.051	0.048
Fig. 4	101,000	0.052	0.049
Fig. 5	51,000	0.026	0.028

Considering the difficulty in making accurate magnetometer measurements, the agreement between the observed and calculated values is as good as could be expected.

Average Flux in Core Due to a Given Number of Uniformly Distributed Ampere-turns

The resultant magnetomotive force acting in any line of force is always equal to the line integral of the magnetizing force (H) completely around the closed

3. These equivalent turns are taken proportional to the actual currents in the coils. The actual number of turns in each of the coils was 35. Hence the equivalent turns in coil No. 1 are $\frac{51.0}{0.84} \times 35 = 2130$.

path formed by this line, *viz.*,

$$4\,\pi\,N\,I = \int H\,d\,x \tag{7}$$

where $N\,I$ is the number of current-turns which link this line of force and $d\,x$ an elementary length in the line of force. In this expression all quantities are in c. g. s. electromagnetic units. When I is expressed in amperes, H in ampere-turns per centimeter (or inch) and x in centimeters (or inches) this expression becomes

$$N\,I = \int H\,d\,x \tag{7a}$$

Consider the special case of an iron core of length l and diameter d magnetized by a coil of N turns, uniformly distributed over its length. Referring to Fig. 2, let H_s be the magnetizing force at any point P on the axis of the core (inside or outside the space occupied by it), which the current in the solenoid which forms the winding *would* produce *were there no iron present.* The value of this magnetizing force in c. g. s. electromagnetic units is[4]

$$H_s = \frac{2\,\pi\,N\,I}{l}\left[\frac{x + 0.5\,l}{\sqrt{r^2 + (x + 0.5\,l)^2}} - \frac{x - 0.5\,l}{\sqrt{r^2 + (x - 0.5\,l)^2}}\right] \tag{8}$$

Let H_m be the magnetizing force at P due to the magnetic poles at the surface of the core. Then the resultant magnetizing force at P is

$$H = H_s + H_m$$

Equation (7), applied to this particular case, then becomes

$$4\,\pi\,N\,I = 2\int_0^{\infty} (H_s + H_m)\,d\,x \tag{9}$$

which may also be written

$$4\,\pi\,N\,I = 2\int_0^{l/2} (H_s + H_m)\,d\,x + 2\int_{l/2}^{\infty} (H_s + H_m)\,d\,x$$

When the length of the magnetizing solenoid is 10 or more times its diameter, it may readily be shown, by integrating equation (8), that

$$2\int_{l/2}^{\infty} H_s\,d\,x = \text{less than 1 per cent of } 4\,\pi\,N\,I$$

Hence, for a core whose length is 10 or more times its diameter, equation (9) becomes

$$4\,\pi\,N\,I = 2\int_0^{l/2} H\,d\,x + 2\int_{l/2}^{\infty} H_m\,d\,x \tag{10}$$

4. (See Pender, "Electricity and Magnetism for Engineers," Part I, p. 231).

As a first approximation, the magnetic poles produced on a core of uniform cross-section, magnetized by a solenoid completely covering it, may be assumed to be distributed in the same manner as the poles induced by a uniform field on an ellipsoid of revolu-

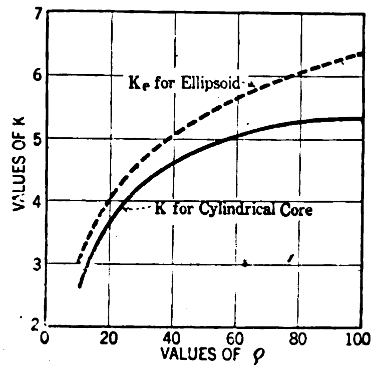

Fig. 6

tion, whose length and maximum diameter are respectively equal to the length and diameter of the rod, and in which the flux through the central cross-section has the same value as the flux through the central cross-section of the given core. Compare the dotted curve in Fig. 6 showing the flux distribution in such an ellipsoid, with the full line curve showing the actual distribution in a rod of uniform cross-section. On this assumption it may be shown[5] that, when l is greater than 10 d,

$$2\int_{l/2}^{\infty} H_m\,d\,x = \frac{B_c\,d^2}{l}\left[\log_e\left(\frac{2\,l}{d}\right) - 1\right] \tag{11}$$

where B_c is the flux density at the center of the core. In this formula all quantities are in c. g. s. electromagnetic units.

Put

$$K_1 = \left(\frac{d}{l}\right)^2\left[\log_e\left(\frac{2}{d}\right) - 1\right] \tag{12}$$

also, let H_a be the average value of the resultant magnetizing force inside the core. Then equation (10) may be written

$$4\,\pi\,N\,I = (H_a + K_1\,B_c)\,l \tag{13}$$

The average flux through a uniformly magnetized ellipsoid of revolution is equal to 2/3 of the flux through its central cross-section. This follows from the fact that the flux through any given cross-section is inversely proportional to the area of this cross-section. Hence, on the assumption that the poles on the given core are distributed in the same manner as the poles on a uniformly magnetized ellipsoid, the flux density B_c at the center of the core is equal to 3/2 times the average flux density B_a in the core. (The actual ratio for the rod in Fig. 3 is 1.36 instead of 1.50). On

5. DuBois, "The Magnetic Circuit in Theory and Practise," (1896), p. 38.

this assumption, equation (**13**) may be written

$$4\,\pi\,N\,I = (H_a + 3/2\,K_1\,B_a)\,l \qquad (\mathbf{13a})$$

Therefore, on the assumptions above stated, the magnetomotive force required to magnetize a core, by means of a uniformly wound solenoid concentric with it and of the same length as the core, is

$$4\,\pi\,N\,I = \left(H_a + \frac{K}{\rho^2}\,B_a\right)l \qquad (\mathbf{14})$$

where

$$\rho = \frac{l}{d} = \frac{\text{Length of core}}{\text{Diameter of core}} \qquad (\mathbf{15})$$

and

$$K = \frac{3}{2}\,(\log_e 2\,\rho - 1) \qquad (\mathbf{16})$$

In these equations I is in absamperes; l is the length of the core, in centimeters; d is the diameter of the core, in centimeters; H_a is the average value of the resultant magnetizing force in the core, in gilberts per centimeter; and B_a is the average flux density in the core, in gausses, *viz.*,

$$B_a = \frac{4\,\phi_a}{\pi\,d^2} \qquad (\mathbf{17})$$

where ϕ_a is the average flux through the core in maxwells.

From the experimental data given in DuBois' "The Magnetic Circuit in Theory and Practise" (p. 41), the value of the factor K for a uniform rod is somewhat less than for an ellipsoid. (The factor K is equal to $\frac{3}{8\,\pi} = 0.1194$ times the factor C employed by DuBois.) In Fig. 6 are given the values of K for a core of uniform cross-section, as calculated from DuBois' experimental data, and also the theoretical values of K for an ellipsoid.

Defining the average permeability μ of the core as the ratio of the average flux density in it to the average of the resultant magnetizing force in it, when both are expressed in c. g. s. electromagnetic units, equation (**14**) for the magnetomotive force required to magnetize the core may be written

$$4\,\pi\,N\,I = \left(\frac{1}{\mu} + \frac{K}{\rho^2}\right)B_a \qquad (\mathbf{18})$$

where μ is in c. g. s. electromagnetic units. Or, substituting for B_a its value in terms of the total average flux ϕ_a (equation **17**), this relation may be written

$$\phi_a = \frac{4\,\pi\,N\,I}{R} \text{ maxwells} \qquad (\mathbf{19})$$

$$R = \frac{4}{\pi\,d^2}\left(\frac{1}{\mu} + \frac{K}{\rho^2}\right)l \text{ oersteds} \qquad (\mathbf{20})$$

This last expression is the total reluctance of the path of the flux through the core, including both the reluctance of the core itself and the reluctance of the return circuit of the flux through the surrounding air.

The reluctance of the core itself is

$$R_i = \frac{4\,l}{\pi\,\mu\,d^2} \qquad (\mathbf{21})$$

It is interesting to note that when the permeability of the core is high, its reluctance is but a small fraction of the total reluctance of the complete magnetic circuit, even though the rod be relatively long. For example, when $\mu = 1000$ and $\rho = 20$,

$$\frac{R_i}{R} = \frac{\frac{1}{\mu}}{\frac{1}{\mu} + \frac{K}{\rho^2}} = \frac{0.001}{0.001 + \frac{3.7}{400}} = 0.0975$$

That is, under these conditions the reluctance of the rod itself is only 9.75 per cent of the total reluctance of the complete magnetic circuit.

The data given in Fig. 3 serves as an experimental check of equations (**19**) and (**20**). The permeability of the core was not measured, but a fair assumption is that it is approximately 1000. The value of ρ for the given core is $\frac{102}{3.28} = 31$. From Fig. 6 the corresponding value of K is 4.27. Whence, from equation (20) the total reluctance of the magnetic circuit is

$$R = \frac{4\,(0.001 + 0.00444) \times 102}{\pi \times (3.28)^2}$$

$$= 0.0656 \text{ oersted.}$$

For a current of 5.98 amperes in 735 turns the magnetomotive force is $4\,\pi \times 735 \times 0.598 = 5530$ gilberts. Whence from equation (**19**) the average flux is

$$\phi_a = \frac{5530}{0.0656} = 84{,}500$$

The actual value of ϕ_a was 99,000. Considering the uncertainty in the assumed value of μ, this may be considered a fairly satisfactory check of equation (**20**).

Comparing Figs. 3 and 4 it is evident that the flux distribution in the core is approximately the same for a winding covering the central half as for a winding covering the entire length of the core. Consequently, equation (**20**) may also be applied, with a fair degree of approximation, even when the winding covers only half the total length of the core. That is, for the same total ampere-turns, the average flux is approximately independent of the axial length of the winding, provided this winding is uniformly distributed over the central portion of the core. This is entirely in accord with the experimental data given in Figs. 3 and 4, *viz.*, the total ampere-turns in the two cases

are 4400 and 4430 respectively, and the average fluxes 99,000 and 101,000 respectively.

SOLUTION OF PROBLEM A. Combining equations (**6**) and (**19**) it follows that the magnetizing force produced at the point P on the axis of a straight core magnetized by a current of I absamperes in a uniformly wound solenoid completely covering this core is,

$$H = \frac{2\,N\,I\,l}{x^3\,R}$$

$$= \frac{\pi\,N\,I\,d^2}{2\,x^3\left(\dfrac{1}{\mu} + \dfrac{K}{\rho^2}\right)} \text{ gilberts per cm.} \qquad (\mathbf{22})$$

where all quantities are in c. g. s. electromagnetic units. This formula is of course applicable only when the point P is at a distance from the center of the core large in comparison with the length of the core.

When I is in amperes, the last relation becomes

$$H = \frac{N\,I\,d^2}{6.37\,x^3\,(1/\mu + K/\rho^2)} \text{ gilberts per cm.} \qquad (\mathbf{22a})$$

In this expression I is the current in the winding, in amperes; N is the number of turns in the winding; d is the diameter of the core, in centimeters; x is the distance of the point P from the center of the core, in centimeters, μ is the average permeability of the core, in c. g. s. electromagnetic units; ρ is the ratio of the length to the diameter of the core, and K is a factor whose value is given by the lower curve in Fig. 6.

Equation (**22**) applied to core and winding corresponding to Figs. 3 and 4 gives for H at a point 315 centimeters from the core the value 0.044 (as compared with 0.048 observed) when the winding completely covers the core (Fig. 3); and the value 0.044 (as compared with 0.049 observed) when the winding covers only the central half of the core (Fig. 4). The permeability is assumed to be 1000 in each case.

PROBLEM B. The self-inductance L of a winding is, by definition, equal to the flux linkages of this winding per unit current in it. When the successive turns of a winding of N turns are all threaded by the same number of lines of force ϕ, the flux linkages are $\lambda = N\,\phi$. When the successive turns are not threaded by the same number of lines of force the flux linkages are

$$\lambda = \phi_1 + \phi_2 + \phi_3 \; . \; . \; . \; . \; \phi_n$$

where ϕ_1, ϕ_2, ϕ_3, etc. are the number of lines of force which thread the successive turns.

Consider the special case of a uniformly wound solenoid of N turns and of axial length l. Let $d\,x$ be the width of a group of turns at an axial distance x from the center of the solenoid, and let ϕ be the flux through this group of turns. The number of turns in the length $d\,x$ is $N/l\;d\,x$. Whence the flux linkages of these turns are

$$d\,\lambda = \frac{N}{l}\,\phi\,d\,x$$

and the total flux linkages of the entire solenoid are

$$\lambda = 2\,\frac{N}{l}\int_0^{l/2} \phi\,d\,x$$

Let ϕ_a be the average value of the flux through the turns which make up the solenoid. Then

$$\int_0^{l/2} \phi\,d\,x = \phi_a\,\frac{l}{2}$$

The total flux linkages of the solenoid are therefore

$$\lambda = N\,\phi_a$$

Let I be the current required to produce the average flux ϕ_a. Then the self-inductance of the solenoid is

$$L = \frac{N\,\phi_a}{I} \text{ abhenries} \qquad (\mathbf{23})$$

where ϕ_a is in maxwells and I in absamperes.

Equation (**23**) is directly applicable to a uniformly wound solenoid on an iron core of the same length as the solenoid. Neglecting the axial component of the flux in the air between the surface of the core and the mean circumference of the solenoid, the average flux which links the turns of the solenoid may be taken equal to the average flux in the core, *viz.*, to the value of ϕ_a given by equation (**19**). Whence, for such a winding the self-inductance is

$$L = \frac{4\,\pi\,N^2}{R} \text{ abhenries} \qquad (\mathbf{24})$$

where R is given by equation (**20**).

The reactance of this winding to a voltage of frequency f is $X = 2\,\pi\,f\,L \times 10^{-9}$ ohms. Neglecting the resistance of the winding, the volt-amperes required to produce in it a current whose *maximum* value is I *absamperes* is

$$\text{Volt-amperes} = X\left(\frac{1}{10} \; . \; \frac{I}{2}\right)^2$$

$$= \frac{4\,\pi^2 f\,(N\,I)^2}{R} \times 10^{-7} \qquad (\mathbf{25})$$

In this equation R is the reluctance in oersteds, as given by equation (**20**). Substituting for $(N\,I)$ its value from (**22**) and for R its value from equation (**20**), there results

Volt-amperes

$$= \frac{4\,\pi\,f\,x^6}{l\,d^2}\left(\frac{1}{\mu} + \frac{K}{\rho^2}\right) H^2 \times 10^{-7} \qquad (\mathbf{26})$$

This formula gives the volt-amperes necessary to produce a magnetizing force of H gilberts per centi-

meter at a point on the axis of a straight core, at a distance of x centimeters from the center of the core, the core being uniformly wound throughout its length. The other symbols in the formula are l = length of core in centimeters, d = diameter of core in centimeters, $\rho = l/d$, K = a factor given by the lower curve in Fig. 6, μ = the average permeability of the core, f = the frequency in cycles per second.

The volume of the core is

$$V = l\left(\frac{\pi}{4}\,d^2\right) = \frac{\pi\,l\,d^2}{4} \text{ cu. cm.}$$

Whence equation (**26**) may also be written

$$\text{Volt-amperes} = \frac{\pi^2 f x^6}{V}\left(\frac{1}{\mu} + \frac{K}{\rho^2}\right) H^2 \times 10^{-7} \qquad \mathbf{(26a)}$$

where V is the volume of the core in cubic centimeters. Note particularly that for a core of given dimensions and given permeability the volt-amperes required are proportional to the *square* of the magnetizing force which it is desired to produce and to the *sixth* power of the distance of the given point from the center of core. Also, for a given volume of core, the longer the core in comparison with its diameter, the more effective will it be.

For example, consider a core 50 feet long and 1 foot in diameter, whose average permeability is 1000 c. g. s. electromagnetic units. The volt-amperes at 25 cycles required to produce a magnetizing force of 0.2 gilberts per centimeter (equal approximately to the horizontal component of the earth's magnetic field) at a point 150 feet from the center of the core (and on its axis) are

$$\frac{4\,\pi \times 25 \times (150 \times 30.48)^6}{(50 \times 30.48)\,(30.48)^2}\left[\frac{1}{1000} + \frac{4.85}{(50)^2}\right] \times (0.2)^2 \times 10^{-7}$$

= 23,900,000 volt-amperes, or 23,900 kilovolt-amperes. To produce this same field intensity 300 feet from the center of the magnet would require 64 times as many kilovolt-amperes, or 1,530,000 kv-a. Or, for the same kilovolt-amperes (23,900), the magnetizing force 300 feet from the center of the magnet would be $1/2^3 = 1/8$th the intensity of the horizontal component of the earth's field.

PROBLEM C. Equation (**23**) is applicable not only to the uniform winding covering the entire length of core, but also to a uniform winding covering only a portion of the core, provided ϕ_a in this equation is taken, not as the average flux for the entire core, but for that particular portion which is covered by the winding. Referring to Fig. 4, the average flux through the central portion of the core covered by the winding (namely, the central 51 centimeters of the core) is the average of ϕ between the limits $x = 0$ and $x = 25.5$. This average flux is 142,000. The self-inductance of this winding (385 turns) is then, from equation (**23**),

$$L_4 = \frac{3.85 \times 142{,}000}{1.15} \text{ abhenries} = 0.0475 \text{ henries}$$

The self-inductance of the uniform winding (735 turns) covering 98 centimeters, or 96 per cent of the length of the core (Fig. 3) is

$$L_3 = \frac{735 \times 102{,}000}{0.598} \text{ abhenries} = 0.125 \text{ henries}$$

Currents of 5.98 and 11.5 amperes respectively in these two windings produced substantially the same external magnetic field. Hence, designating the volt-amperes for the two cases P_4 and P_3 respectively, and noting that

$$P_4 = 2\,\pi f L_4 \times 10^{-9}\left(\frac{1}{10}\;\frac{11.5}{\sqrt{2}}\right)^2$$

$$P_3 = 2\,\pi f L_3 \times 10^{-9}\left(\frac{1}{10}\;\frac{5.98}{\sqrt{2}}\right)^2$$

there results

$$\frac{P_4}{P_3} = \frac{0.0475}{0.125}\left(\frac{11.5}{5.98}\right)^2 = 1.40$$

The core which has a winding covering only its central half therefore requires, to produce the same external magnetic field, 40 per cent more volt-amperes for excitation than the core which is uniformly wound throughout its entire length. The exact percentage difference will of course depend upon the permeability and the relative dimensions of the ore. However, irrespective of the permeability and dimensions, the short winding will always require more volt-amperes, due to the fact that the average flux which links its turns is always greater than the average flux for the entire length of the core.

When the winding is so distributed as to give a practically constant flux through each cross-section of the core, as in Fig. 5, its self-inductance is

$$L_5 = \frac{N\,\phi}{I}$$

where N is the total number of turns in the winding and I the current. The self-inductance of the winding corresponding to Fig. 5 is therefore

$$L_5 = \frac{5253 \times 51{,}500}{0.084} \text{ abhenries} = 3.22 \text{ henries}$$

The magnetizing force produced by a current of 0.84 amperes in this winding, at a point on the axis of the core 315 centimeters from its center, was 0.028, as against 0.048 for a current of 5.98 amperes in the uniform winding of 735 turns covering the entire length of core. Neglecting variations in permeability, the current required in the full-length uniform winding, to produce a magnetizing force of 0.028, would be

$\frac{0.028}{0.048} \times 5.98 = 3.49$ amperes. Hence, for the external magnetic field, the relative volt-amperes required for the two windings would be in the ratio of

$$\frac{P_5}{P_3} = \frac{3.22}{0.125} \left(\frac{0.84}{3.49} \right)^2 = 1.49$$

A lumped winding at the two ends of the core therefore also requires more volt-amperes for excitation than a uniform winding covering the entire length of the core.

For the maximum external field per volt-ampere of excitation, the winding should therefore cover the entire length of the core and be uniformly distributed.

PROBLEM D. The volume of an ellipsoid of revolution, of a given length and maximum diameter is 2/3 of a volume of a cylinder of the same length and same diameter. Assuming a uniformly wound solenoid to produce a uniform magnetic field in the space enclosed by its winding (which is approximately true except for the region near its two ends), the ampere-turns required to magnetize such a core are, from equation (**13**),

$$4 \pi N I = (H_a + K_1 B_c)$$

where K_1 is given by equation (**12**) and

$$B_c = \frac{4 \phi_c}{\pi d^2}$$

and ϕ_c is the flux through the central cross-section of the ellipsoid. This maximum flux ϕ_c is equal to 3/2 times the average flux ϕ_a through the ellipsoid. Also, $H_a = \frac{B_c}{\mu}$. Whence

$$4 \pi N I = \frac{6}{\pi d^2} \left(\frac{1}{\mu} + K_1 \right) \phi_a$$

and therefore

$$\phi_a = \frac{4 \pi N I}{R_e} \tag{27}$$

where

$$R_e = \frac{4}{\pi d^2} \left(\frac{3}{2 \mu} + \frac{3}{2} K_1 \right)$$

As before equation (**16**), put

$$K_e = \frac{3}{2} \left[\log_e 2 \rho - 1 \right]$$

(The subscript "e" is here used to designate that this value of K refers to an ellipsoid). Then

$$R_e = \frac{4}{\pi d^2} \left(\frac{3}{2 \mu} + \frac{K_e}{\rho^2} \right) \tag{28}$$

The value of K_e for an ellipsoid is given by the upper curve in Fig. 6.

Comparing equation (**28**) with equation (**20**), and noting that K_e for an ellipsoid is greater than K for a cylinder, it is evident that, although the volume of an ellipsoid of revolution is less than the volume of a cylinder of the same length and cross-section, the reluctance of the complete path of the flux in the case of the ellipsoid is greater than the reluctance of the complete path of the flux in the case of a cylinder. This greater reluctance is due to the fact that the flux density in an ellipsoid has the same value throughout its length, whereas in a cylindrical core the *average* flux density is only about 2/3 of the value at the center.

The self-inductance of a uniform winding covering the entire length of an ellipsoidal core is

$$L = \frac{N \phi_a}{I}$$

where I is the current and ϕ_a the average flux through the core. Substituting for ϕ_a its value from equation (27), there results

$$L = \frac{4 \pi N^2}{R_e}$$

From equation (**25**) the volt-amperes required for excitation, to produce a maximum current of I absamperes, is then

$$\text{Volt-amperes} = \frac{4 \pi^2 f (N I)^2}{R_e} \times 10^{-7} \tag{29}$$

where I is in absamperes (maximum value) and R is in oersteds. Substituting for $(N I)$ its value from (**27**) there results

$$\text{Volt-amperes} = \frac{f R_e}{4} \phi_a^2 \times 10^{-7}$$

Substituting for ϕ_a its value from equation (**6**), and for R_e its value from (**28**), there results

$$\text{Volt-amperes} = \frac{4 \pi f x^6}{l d^2} \left(\frac{3}{2 \mu} + \frac{K_e}{\rho^2} \right) H^2 \times 10^{-7} \tag{30}$$

The volume of an ellipsoid of revolution is

$$V = \frac{\pi}{6} l d^2$$

Whence equation (**30**) may be written

Volt-amperes

$$= \frac{\pi^2 f x^6}{V} \left(\frac{1}{\mu} + \frac{2}{3} \frac{K_e}{\rho^2} \right) H^2 \times 10^{-7} \tag{30a}$$

Comparing this expression with equation (**26a**) for a cylindrical core it is evident that for the same volt-amperes and same volume of iron, the magnetizing force H_e produced at a point at a given distance x from the center of an ellipsoid core, and the magnetizing force H produced at a point at an equal distance from the center of a cylindrical core, are in the ratio

$$\frac{H_e}{H} = \sqrt{\frac{\frac{1}{\mu} + \frac{K}{\rho^2}}{\frac{1}{\mu} + \frac{2}{3}\frac{K_e}{\rho^2}}} \quad (31)$$

For example, for $\mu = 1000$ and $\rho = 31$, $K = 4.27$ and $K_e = 4.70$. Whence

$$\frac{H_e}{H} = 1.13$$

For these conditions the effectiveness of the ellipsoid core is only 13 per cent greater than that of a cylindrical core. This gain would hardly justify the labor involved in tapering the core.

As a rough experimental check on the effect of tapering a core, the core of iron wires above described was excited by a current of 10 amperes in a coil covering the central 61 centimeters of its axial length. The magnetizing force at a point 300 centimeters from the center of the core was measured by means of a magnetometer, and found to be 35.2 units (arbitrary scale). The core was then tapered at each end (by cutting off the wires of successive layers to different lengths), making a taper from 3.28 to 2.1 centimeters in a distance of 19 centimeters. The magnetizing force at the same point as before for the same current in the winding (10 amperes) was found to be reduced to 33.7 units (on the same arbitrary scale). The decrease in the volume of the core was 11.3 per cent, and the decrease in the magnetizing force was 4.3 per cent.

Since for a fixed number of volt-amperes the magnetizing force at the external point varies as the *square-root* of the volume of the core (equation **30a**), had the tapered core been of the same volume as the cylindrical core, (*i. e.*, increased from a volume of 0.87 to 1.00, or 15 per cent) the magnetizing force for the same number of volt-amperes in the two cases would have been in the ratio of

$$\frac{H_t}{H} = \frac{(33.7)\sqrt{1.15}}{35.2} = 1.03$$

That is, for the same volume and same volt-amperes the tapered core used in the experiment would have produced a magnetizing force only 3 per cent greater than a cylindrical core.

REORGANIZATION OF NELA RESEARCH LABORATORIES

Nela Research Laboratory was organized in 1908 under the Directorship of Dr. Edward P. Hyde as The Physical Laboratory of the National Electric Lamp Association. The name was changed to Nela Research Laboratory in 1913, when the National Electric Lamp Association became the National Lamp Works of General Electric Company. For some years the Laboratory was devoted exclusively to the development of those sciences on which the art of lighting has its foundation, but in 1914 the functions of the Laboratory were extended by the addition of a small Section of Applied Science, which had an immediate practical objective.

The Section of Applied Science is now being largely extended as a separate Laboratory of Applied Science under the immediate direction of Mr. M. Luckiesh, who becomes Director of Applied Science, and a new building is being constructed to house this branch of the work, which will be carried forward with a staff of several physicists, an engineer, an architect and a designer, together with the necessary technical and clerical assistants.

Dr. Ernest Fox Nichols, formerly President of Dartmouth College, and more recently Professor of Physics at Yale University, has accepted an invitation to assume the immediate direction of the Laboratory of Pure Science under the title of Director of Pure Science. The work of this Laboratory, which will be continued in the present building, will be somewhat further extended under the new organization.

The Laboratory of Pure Science and the Laboratory of Applied Science will together constitute the Nela Research Laboratories, and will be co-ordinated under the general direction of Dr. Hyde, who becomes Director of Research.

INVESTIGATIONS IN ELECTROLYSIS

Early in the year, definite arrangements were made with the American Committee on Electrolysis, which represents all of the great national associations of utility companies, for cooperative work between that Committee and the Bureau of Standards in conducting an extensive research in the field of electrolysis mitigation. After this arrangement had been made, the Committee asked the Bureau to outline a program of research work to be carried out jointly, and such a program was formulated by the Bureau and approved by the Committee.

During the last four months a number of somewhat extended investigations have been carried out in cooperation with this Committee in several middle Western cities. This work has been confined largely, and almost exclusively, to the effect of pipe drainage on underground systems, especial attention being given to the possibility of joint electrolysis on high resistance joints and interchange of current between drained systems. Some attention has also been given to the three-wire systems of power distribution and also to automatic substation installations as a means of electrolysis mitigation. This joint investigation is an extremely important one and it is hoped that means will be found for continuing it during the coming year.

The Current-Carrying Capacity of Lead-Covered Cables

BY RALPH W. ATKINSON

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This article gives data whereby the carrying capacity of lead-covered cables can be calculated on the basis of thermal limitations. Carrying capacity as limited by voltage drop or economical considerations is not discussed. The article shows how further data can be applied as these are determined.

An appendix contains some numerical examples illustrating the use of the data. It also contains a chart by which it is possible to determine graphically, for given conditions, the carrying capacity of three-conductor paper and varnished cloth cables installed in conduits.

There is also included a chart illustrating the relation between the various temperatures and temperature rises of a group of lead-covered cables.

THE load that a cable may safely carry is dependent upon properties intrinsic to the cable itself and upon the temperature of the immediate surroundings of the cable. The properties of the cable which affect its carrying capacity are the maximum allowable operating temperature and the temperature rise—due to the load—of the conductor above the temperature of the cable surroundings.

Maximum Allowable Operating Temperature. The American Institute of Electrical Engineers has recommended the following as the safe limits of maximum allowable operating temperature for various kinds of insulation.

Paper..............(85 deg. cent. – E)
V. C................(75 deg. cent. – E)
Rubber.............(60 deg. cent. – 0.25 E)

Where E is the r. m. s. of the operating voltage in kv. between conductors.

Abnormal temperatures seriously affect either—or both—of the electrical and mechanical properties of the dielectric of high and low-voltage cables. Most of the effect upon the electrical properties is an indirect result of the effect of heat upon their mechanical properties. A low-voltage cable may sustain a great amount of damage to the dielectric and still be entirely serviceable—if undisturbed. However, the higher the operating voltage of the cable, the less the degree of damage which the cable may sustain and still be likely to continue in successful operation.

Therefore whatever may be judged to be the allowable limit of temperature at which low-voltage cable may operate, necessarily a more strict limitation must be placed upon the temperature at which a high-voltage cable may operate, and the higher the voltage of the cable, the lower will be the allowable temperature limit.

Apart from the physical condition of the dielectric as affected by temperature, a very important consideration is that the dielectric losses are proportionally very much greater at higher temperatures. This is of no practical importance in low-voltage cables but in the case of high-voltage cables may sometimes set a definite limit lower than that set by other causes.

The temperature limits given by the A. I. E. E. rules, for cables operating at different voltages, are entirely rational, in the light of the present development of the art. However, different service conditions may warrant variation from rules which apply to general conditions; thus cables installed under extraordinarily severe conditions, perhaps cannot be expected to have a long life and may justifiably be operated at temperatures that will be known to produce a short life.

The Base Temperature. An unloaded cable will normally assume the temperature of the medium in which it is placed. Thus, a cable that is carrying no load when placed in water, will assume the temperature of the water. If placed in air, it will assume the ambient temperature of the air, unless it receives radiated heat from some hot body such as the sun. Likewise, an unloaded cable when placed in the earth or in a conduit will assume the temperature of the earth.

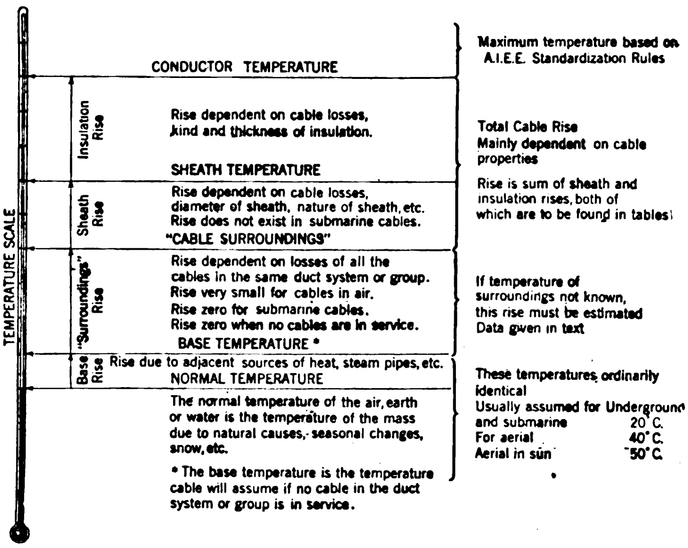

FIG. 1—CHART ILLUSTRATING THE RELATION BETWEEN THE VARIOUS TEMPERATURES AND TEMPERATURE RISES IN LEAD-COVERED CABLES

In some places the presence of steam pipes, furnaces, etc., may cause the temperature of the earth to exceed the normal earth temperature, the normal temperature being that due to natural causes.

The temperature which an unloaded cable or group of cables assumes when placed in position to operate will be called its "Base Temperature".

Temperature Rise Caused by Load. If load is now applied to the cables heat is generated and must be dissipated through the surrounding media. This will cause the cables to rise in temperature.

The rise in temperature of the cables may be divided into three parts; the rise of the conductor temperature above sheath temperature; the rise of sheath temperature above the temperature of surroundings; and the rise of the surroundings above the base temperature.

Temperature Rise of Conductor. The rise in temperature of the conductor above the sheath is a function of the thickness and kind of insulation and of the load upon the cable. It is easily found by laboratory experiment and as it is practically independent of conditions external to the cable it forms a very convenient basis for calculation.

Temperature Rise of Sheath. The temperature rise of the sheath above the cable surroundings is a function of the diameter of the cable, the nature of the sheath surface and cable surroundings and of the load upon the cable.

The effect of the surroundings upon this rise is illustrated by the fact that for a cable lying in water there is little surface resistance between the cable sheath and the water so that the sheath will assume a temperature so near that of the water that the difference may usually be disregarded.

Total Cable Rise. Since the temperature rise between the inner and outer surfaces of the sheath is very small it may be neglected and the sum of the conductor rise above sheath temperature plus the temperature rise of the sheath above the temperature of the surroundings constitutes the entire rise of the conductor above the cable surroundings. (Insulation rise plus sheath rise). This rise will be called the total cable rise.

Rise of Cable Surroundings. If the medium surrounding a cable is free to flow as where the cable is placed in free air or water, heat is readily carried away from it and there is little or no rise of the surrounding medium. This does not apply where a large number of cables are closely placed together in air.

If, however, a cable or group of cables is placed in the earth, there is a rise in temperature of the surroundings because of their thermal resistance. This rise in temperature of the surroundings is, as a first approximation, proportional to the total energy dissipated by all the cable in the immediate vicinity, or in the same conduit system. We can therefore say that for a given type and size of conduit structure the temperature rise of the system is equal to a certain number of degrees per watt loss per foot of duct structure. This rise in degrees cent. per watt per foot of duct structure will be called the "Heating Constant" of the duct system.

There are not at present sufficient data available to permit the giving of accurate numerical values for this factor for different conditions. The data which are available indicate that it will usually fall between the limits 0.6 to 1.6 depending upon the size of duct structure and upon the nature of the surrounding soil. One (1.0) seems to be a good and reasonably safe average figure for a conduit containing up to say 16 ducts surrounded by earth with a normal amount of moisture. More data should be obtained showing the effect of different soil conditions and of the size and shape of the conduit system upon the average constant of the structure. Also these data should show how the constant for different parts of the cross-section varies and how it is affected by the distribution of the cables in the structure. The heating constant multiplied by the watts loss per foot of all the cables in the conduit gives the temperature rise of the cable surroundings.

The Temperature of the Cable Surroundings. The temperature of the surroundings is equal to the temperature rise of these surroundings added to the base temperature.

Because of the insufficient data pertaining to the heating constant, the most accurate results can be obtained from the data here presented only when the temperature of the cable surroundings is known or can be measured.

For a cable installed in a duct, the "surrounding temperature" is taken as that of the duct wall and not that of the air in the duct. It is not practical to measure the temperature of the air in the duct since a measurement of this may give anything between the temperature of the cable sheath and that of the duct wall. Also it has been shown by experiment that normally the rise of a cable over the duct wall temperature is very nearly the same as the rise over ambient air temperature of a similar cable with the same load but suspended in free air.

Measurement of Duct Temperatures. Usually the temperature of the duct walls surrounding any cable may be determined with good accuracy by measuring the temperature in an adjacent idle duct at the same distance from the outside of the conduit or one adjacent but nearer the center of the conduit system. In the former case, the temperature of the idle duct will be lower by a very small amount and in the latter case the temperature of the idle duct will be very nearly the same as the walls of the working duct.

Another way of measuring the duct wall temperature is actually to make the measurement within the working duct, but after cutting off the current and voltage within from one-half to one hour. This is allowable on account of the relatively great amount of time required by a duct system to change its temperature. If the temperature is measured while the cable is working, it is not known what temperature is being measured. (See Atkinson & Fisher A. I. E. E. 1913).

The Total Allowable Temperature Rise of Cable. If the maximum allowable operating temperature is

known or assumed, and the temperature of the cable surroundings is known, the total allowable rise of the cable is found by subtracting the temperature of the surroundings from the maximum allowable temperature. Where the temperature of the surroundings is not known and must be estimated, the total allowable rise of cable and surroundings is found by subtracting the base temperature from the maximum allowable temperature. When the sheath temperature is known the maximum rise of the conductor over the sheath temperature is found by subtracting the temperature of the sheath from the maximum allowable temperature. Obviously, the carrying capacity of a cable is limited by its hottest portion. Hence, the maximum allowable temperature rise must be figured for that portion of the cable lying in the hottest surroundings.

The Losses. The losses that cause the rise in temperature of a cable are the conductor $I^2 R$ loss (including skin effect and eddy current losses in the conductor), dielectric loss, and sheath current loss.

The conductor $I^2 R$ loss normally is by far the largest of the above losses; in fact, often this loss only, need be considered as affecting the current-carrying capacity of a cable. This loss is proportional to the conductor resistance and to the square of the current. The skin effect and eddy current losses may be considered simply as increasing, by a certain amount, the conductor resistance. That is, the conductor may be considered to have an effective resistance sufficient to account for all the losses within it. The conductor loss produces rise in all parts of the heat path, conductor above sheath, sheath above ambient air, or duct wall, and rise of duct above base temperature for underground cables.

Dielectric losses affect the sheath and conductor rise exactly as do an equal amount of conductor loss. Unless the dielectric losses are very large no important error is introduced by considering that their effect upon the insulation and conductor rise is the same as an equal amount of conductor loss. Where the rise inside the sheath due to dielectric loss is large, no accurate general rule for determining that rise can be made.

Sheath losses produce no rise of the conductor above sheath but affect the sheath rise and duct rise in exactly the same way as an equal loss in the conductor. Sheath losses are important normally only in single-conductor a-c. cables.

Calculation of Carrying Capacity. The general method of procedure is practically the same in every case. First the total rise caused by a known loss is found and from this the loss is calculated which will produce the maximum allowable rise. From this the allowable current is calculated.

Consider as a specific case a three-conductor low-voltage cable operating in free air. The recommended maximum operating temperature is fixed by the kind of insulation and the operating voltage. The allowable temperature rise is found by subtracting the ambient air temperature from the recommended operating temperature. From tables I and II the rise in temperature of the conductor above sheath due to a given number of watts loss is found. From the same tables the rise in temperature of the sheath above ambient air temperature is found for the same watts loss. The sum of these temperature rises gives the total temperature rise produced by this amount of loss.

A three-conductor cable normally has very little sheath loss. The total losses in this case are considered as conductor $I^2 R$.

TABLE I
THREE-CONDUCTOR CABLES INSULATED WITH 3/32-IN. PLUS 3/32-IN. PAPER.

Sizes A. W. G.	Cir. mils.	Watts loss per foot to produce 25 deg. cent. rise	Current in amp. watts per cond. to produce as $I^2 R$.
10	10,380	2.90	28.4
9	13,090	3.00	32.4
8	16,510	3.15	37.2
7	20,820	3.30	42.3
6	26,250	3.46	49.0
5	33,100	3.52	55.7
* 4	41,740	4.00	66.8
3	52,630	4.17	76.5
2	66,370	4.35	87.9
1	82,690	4.60	101
0	105,500	4.82	115
00	133,100	5.10	134
000	167,800	5.42	156
0000	211,600	5.80	179
	250,000	6.05	202
	300,000	6.40	227
	350,000	6.75	252
	400,000	7.03	274
	450,000	7.25	295
	500,000	7.50	314
	600,000	8.00	358
	750,000	8.77	419

* Conductors smaller than No. 4 are figured as solid.

In figuring the current to produce the watts as $I^2 R$ loss the resistance of the conductor was calculated at 65 deg. cent. which is near the operating temperature. An allowance of 3 per cent in resistance was made for stranding and cabling.

Column 3 of tables I and II gives the current which will produce the above number of watts as $I^2 R$ loss. The total rise due to this current being known, the current which will produce the total allowable temperature rise is found by multiplying the table current by the square root of the ratio of the allowable temperature rise to the rise produced by the table current.

Effect of Dielectric Loss. As this is a low-voltage cable dielectric losses are neglected. Had it been a high-voltage cable with dielectric losses present in important amount the procedure would have been slightly changed.

It is assumed that the amount of the dielectric loss at the operating voltage and temperature is known. After finding the temperature rise caused by the table watts the temperature rise caused by the dielectric loss is found by direct proportion and subtracted from

the total allowable rise. This leaves the allowable rise that may be caused by conductor $I^2 R$ loss. The permissible current is then found in the same way as before.

Effect of Sheath Losses. Had this been a single-conductor cable with sheath loss present in known amount, the procedure would have been similar except as follows. The sheath loss varies as the square of the conductor current and can therefore be expressed in per cent of the conductor loss. When sheath loss is present the total sheath rise is the rise produced by the conductor loss increased by this percentage.

Submarine Cable. Had this cable been installed in water the sheath rise would have been neglected; with this exception, the method is the same as before.

Where cables are already installed in ducts and already operating the problem often is to find the working temperature corresponding to the load being carried on the cables. The duct wall temperature under operating conditions should first be measured. The conductor rise and sheath rise for table current are then found. The sum of these rises multiplied by the square of the ratio of the current in the cables to the table current, gives the total cable rise produced by the load current. If the cables are operating at high voltage the rise caused by the dielectric losses (which must be known) at this temperature is found and also added. If this rise is enough to further influence the loss, further allowance must be made for this. Final determination can usually be found readily by very little "cut and try".

TABLE II

THREE-CONDUCTOR CABLES

A. Temperature rise of conductor above sheath in degrees centigrade produced by the watts in table I.

B. Temperature rise of sheath above cable surroundings produced by the watts in table I.

Size	3 + 3/3 Paper		4 + 4/32 Paper		6 + 6/32 Paper		8 + 8/32 Paper		10 + 10/32 Paper	
	A	B	A	B	A	B	A	B	A	B
* No. 10 Round	11.4	13.6	12.8	12.2	14.6	9.4	....	....	....	....
No. 4 "	10.6	14.4	12.5	12.8	14.7	9.8	16.3	8.5	....	....
No. 1/0 "	10.5	14.5	12.0	12.9	14.8	10.7	16.7	9.8	18.3	7.9
No. 4/0 "	10.4	14.6	12.1	13.2	15.0	11.3	17.2	10.4	19.1	8.8
350,000 Cir. Mils Round	10.4	14.6	12.2	13.3	15.2	11.6	17.5	10.8	19.6	9.1
500,000 " " "	10.4	14.6	12.4	13.3	15.4	11.7	7.8	11.3	20.0	9.3
600,000 " " "	10.5	14.5	12.6	13.4	15.6	11.8	18.1	11.4	20.3	9.5
750,000 " " "	10.6	14.4	12.8	13.5	15.9	12.0	18.3	11.3	....	....
No. 4 Sector	9.7	15.8	11.6	13.6	14.5	10.7	....	....	....	....
No. 2 "	9.1	15.8	11.0	13.7	14.0	11.0	16.1	9.1	....	....
No. 0 "	8.6	15.9	10.5	14.0	13.4	11.4	15.8	9.5	17.7	8.8
No. 0000 "	8.4	16.2	10.1	14.6	13.0	12.1	15.5	10.4	17.8	9.1
350,000 Cir. Mils Sector	8.4	16.4	9.9	14.9	12.9	12.6	15.4	11.1	17.9	9.8
500,000 " " "	8.5	16.5	9.9	15.1	12.9	13.0	15.4	11.5	17.9	10.2
600,000 " " "	8.5	16.5	10.	15.2	13.1	13.2	15.5	11.7	17.8	10.6
750,000 " " "	8.7	16.5	10.3	15.2	13.4	13.4	15.8	11.9	....	....

* Conductors smaller than No. 4 are figured as solid.

Cables Installed in Conduits. The carrying capacity of a number of cables in a duct structure is calculated in the following manner.

If the duct wall temperature is not known the total allowable rise is found by subtracting the base temperature from the recommended maximum operating temperature.

The conductor rise and sheath rise caused by the table current is found as before. The rise of the surroundings due to this current is found by multiplying the total loss per foot in all the cables in the duct structure by the "Heating Constant."

The sum of these three rises gives the total rise caused by the table current. The permissible current is then found by multiplying the table current by the square root of the ratio of the total allowable rise to the rise (including rise of surroundings) produced by the table current.

Dielectric losses and sheath losses are taken care of in the same manner as before, remembering that these also affect the rise of surroundings.

Artificial Means of Cooling. When it is necessary to transmit very large amounts of power in a single conduit structure, artificial means of cooling may be required. The carrying capacity of a duct structure already fully loaded with cables often may be increased considerably by forcing air through the ducts. This is done by installing suitable fans at alternate manhole openings. The air cools the ducts not only by carrying away the heat but also by reducing the temperature difference between the sheath and duct wall.

Under proper conditions a much more effective method is that of cooling by water. This may be done either by actually allowing the water to flow through the ducts or by allowing it to moisten the earth around the structure, thus greatly decreasing the heating constant.

Of course many practical difficulties stand in the way of common application of these methods.

Effect of Load Factor. Cables installed in air, submarine cables, and single cables installed in a conduit system reach their maximum temperature quickly

after load is applied and hence their carrying capacity for loads of one or two hours duration, is not materially increased over that for continuous loads. A conduit system has relatively a very high heating capacity and takes many times as long to reach its final temperature. Hence in a conduit system where the duct rise is a large portion of the total rise the duct rise is decreased by low load factor. Thus the reduction of carrying capacity caused by conduit heating by the group of cables is less for intermittent than for continuous loading.

With proper data concerning this effect the numerical calculation may be made in the same manner as for a decrease in heating constant.

See Atkinson and Fisher, A. I. E. E. 1913.

The Tables. The original data for these tables were obtained from direct experiment, that is temperature rise measurements on a number of different sizes of cables and with different insulation thicknesses. The data have now been correlated on the basis of a definite thermal resistivity of the insulation and surface resistivity of the sheath. In so doing use has been made of the paper by the writer in the June 1919 PROCEEDINGS which gives the relation between resistances and resistivities of three-conductor cables.

The specific value of thermal resistivity used in the tables (900 centigrade degrees per watt centimeter) is a representative value for saturated paper insulation. Correction for other values than 900 may readily be made by direct proportion. Varnished cambric has about the same value as has paper. The value for rubber may be taken as about 650.

The value of surface resistivity used is 1200 degrees per watt per square centimeter. This corresponds to the value for a clean bright sheath. The rise is about 20 per cent lower for a sheath properly painted black.

Accuracy of Method. The experimental basis for the tables was obtained with cables suspended in air and with the copper at a high temperature, that is, with a high cable rise. The currents in the tables are figured on the basis of copper resistance at 65 deg. cent. The tables are therefore correct for high cable rise and 65 deg. cent. maximum temperature.

If conditions are such that the maximum temperature remains unchanged but that the surrounding temperature increases, there will be some error in the assumption that the temperature rise varies directly as the loss. The maximum percentage error occurs however for the lowest temperature rise and the absolute amount of the error is never large. Thus the cable rise is quite properly taken as proportional to the loss or to the square of the current.

If conditions are such that the maximum operating temperature varies much from 65 deg. cent., it will be found that the effect of the change in copper resistance is in the opposite direction to that produced by change in the thermal resistance of the surface of the sheath. The cable rise for the same current will not be greatly altered. The duct rise, however, will increase with the total losses even faster perhaps than in direct proportion, due to the drying effect of the high temperature upon the ducts and hence the duct rise should be calculated as proportional to the actual losses.

From data on duct rise which are now being obtained a supplementary article will be prepared showing the effect upon the heating constant of distribution of load in the conduit and also of the shape of the daily load curve.

Three-Conductor Current and Watts to Give 25 Deg. Cent. Rise. Table I gives for a three-conductor cable insulated with $\frac{3+3}{32}$ paper, the watts loss in the conductors required to raise them 25 deg. cent. above the temperature of the cable surroundings, where the cable is freely suspended in air. The table also gives the current that would produce the above watts per foot as conductor $I^2 R$ loss with the copper at 65 deg. cent.

Three-Conductor Rise With Various Insulation Thicknesses. Table II shows for three-conductor cable the effect of insulation thickness upon cable temperature rise. The temperature rise of the conductor over sheath temperature, produced by the watts in table I is given for various thicknesses of insulation.

This table also gives the sheath rise over surroundings for cables with various thicknesses produced by the watts from table I.

The second part of this table gives similar data for sector cable. It will be noted that the insulation and sheath rise for the sector cables are quite different from those for round cables with the same insulation thickness and conductor area, but that the sums of these rises are nearly the same. The maximum difference between the total cable rises is about 7 per cent in favor of the sector. This would mean a maximum of about 3 ½ in carrying capacity for a cable installed in air. For most sizes the difference is of no consequence. For cables installed in ducts, the difference is still further reduced.

Unequal Belt and Conductor Insulation. The direct values given in the table are for cables having equal belt and conductor insulation. However, the values for a cable having unequal belt and conductor insulation can easily be found by the following simple rules. The temperature rise of conductor above sheath, varies but little as long as the total insulation between the conductor and the sheath does not change. Thus a No. 0000 cable insulated with $\frac{8+4}{32}$ paper will have nearly the same insulation rise as a No. 0000 cable insulated with $\frac{6+6}{32}$ paper.

The rise of temperature of the sheath of a cable is

TABLE III

SINGLE-CONDUCTOR CABLES INSULATED WITH 4/32-in. PAPER.

Size A. W. G.	Cir. mils	Watts loss per foot to give 25 deg. cent. rise	Current in amp· per condr. to produce watts as $I^2 R$
14	4,107	1.56	22.6
13	5,178	1.62	25.6
12	6,530	1.68	29.0
11	8,234	1.74	33.5
10	10,380	1.80	38.0
9	13,090	1.88	43.7
8	16,510	1.95	50.
7	20,820	2.04	57.6
6	26,250	2.14	66.
5	33,100	2.24	75.8
4	41,740	2.47	89.8
3	52,630	2.61	103 5
2	66,370	2.76	120.
1	83,690	2.92	128.5
0	105,500	3.12	161.
00	133,100	3.32	186.
000	167,800	3.56	216
00C0	211,600	3.80	251
	250,000	4.00	280
	300,000	4.23	316
	350,000	4.44	342
	400,000	4.65	382
	450,000	4.83	413
	500,000	5.02	444
	600,000	5.33	501
	700,000	5.65	558
	800,000	5.94	600
	900,000	6.22	665
	1,000,000	6.46	713
	1,100,000	6.65	758
	1,200,000	6.90	807
	1,300,000	7.11	850
	1,400,000	7.32	996
	1,500,000	7.51	940
	1,600,000	7.72	984
	1,700,000	7.90	1025
	1,800,000	8.07	1065
	1,900,000	8.24	1101
	2,000,000	8.40	1150
	2,500,000	9.50	1365
	3,000,000	9.92	1530
	4,000,000	11.17	1870
	5,000,000	12.3	2290

* Conductors smaller than No. 4 are figured as solid.

dependent on the sheath diameter and not upon the distribution of the insulation. Therefore, to find the sheath rise of a cable with insulation divided unequally between conductor, and belt, simply find by use of the table the rise for a cable of equal belt and conductor insulation of the same diameter.

The chart which immediately follows the tables gives directly the diameters of cables having unequal belt and conductor insulation in terms of the diameter of a cable having equal belt and conductor insulation.

Single-Conductor Watts and Current to Give 25 Deg. Cent. Rise. Table III gives for a single-conductor cable insulated with 4/32-in. paper the watts required to produce a 25 degree centigrade rise of conductor over cable surroundings. The currents necessary to produce these watts as $I^2 R$ loss are also given.

TABLE V

ROUND DUPLEX CABLES

A—Temperature rise of conductor above sheath in degrees centigrade produced by 2/3 of the watts in table I, *i. e.*, the same current per conductor.

B—Temperature rise of sheath above cable surroundings in degrees centigrade produced by 2/3 of the watts in table I, *i. e.*, the same current per conducotr.

Size	6 + 4 / 64	Paper	9 + 6 / 64	Paper	12 + 8 / 64	Paper
	A	B	A	B	A	B
No. 10 A. W. G	9.0	10.	11.3	7.9	12.5	6.6
" 4 "	8.8	10.8	11.2	9.0	12.6	7.7
" 0 "	8.8	10.6	11.1	9.1	12.7	7.9
" 0000 "	8.9	10.6	11.1	9.2	12.8	8.2
350,000 C. M.	9.0	10.5	11.1	9.4	12.9	8.5
500,000 "	9.1	10.4	11.2	9.4	13.1	8.6
600,000 "	9.1	10.4	11.4	9.5	13.2	8.7
750,000 "	9.2	10.5	11.6	9.6	13.5	8.9

Single-Conductor Rise with Various Thicknesses of Insulation. Table IV shows the effect of different thicknesses of insulation on the conductor and sheath rise of single-conductor paper cables.

Different thicknesses of lead will have slight effect upon the sheath rise.

Two-Conductor Cables. Though not as widely used as the single and three-conductor forms, two-conductor cables are of sufficient importance to warrant special mention. The common forms are named for the shape of the sheath, "round" and "flat", the latter having a sheath of an oblong or sometimes a figure 8 shape. Tables V and VI respectively give data for cables of these forms. Not as many experimental data are available for these as for one and three-conductor

TABLE IV—SINGLE-CONDUCTOR CABLES

A. Temperature rise of conductor in degrees cent. over sheath attained with watts in table III.

C. Temperature rise of conductor in degrees cent. over temperature of cable surroundings, conductor rise and sheath rise attained with watts in table III.

Cond.	4/32	Pap.	6/32	Pap.	8/32	Pap.	10/32	Pap.	16/32	Pap.	24/32	Pap.	32/32	Pap.
Size	A	C	A	C	A	C	A	C	A	C	A	C	A	C
14	11.6	25	....	....	....	....	....	....	....	....	....	....	....	....
8	9.6	25	12.8	25.9	....	....	....	....	....	....	....	....	....	....
2	7.9	25	10.9	25.9	12.9	25.7	15.	26.9	....	....	....	....	....	....
0	7.5	25	10.3	25.9	12.4	26.0	14.6	27.0	19.3	28.9	23.9	31.3	27.3	32.7
250,000	6.6	25	9.5	26.3	11.8	26.7	14.1	27.9	19.3	30.1	24.5	33.2	27.4	33.3
500,000	6.2	25	9.1	26.6	11.2	27.1	13.7	28.6	19.3	31.	24.9	34.7	27.6	34.8
1,000,000	5.7	25	8.5	26.6	10.8	27.6	13.2	29.0	19.3	31.6	25.5	36.6	29.6	37.8
2,000,000	5.4	25	8.1	26.6	10.4	27.9	12.8	29.5	19.3	33.	26.	38.4	30.9	40.4
5,000,000	5.2	25	7.7	26.9	10.2	28.5	12.7	30.7	19.3	35.4	26.9	41.2	....	....

cables and thus these tables are more strictly a result of mathematical calculation than are tables I to IV, but some direct experimental data on two-conductor forms are available so it is known that the calculated values are in line with actual practical values.

Approximate carrying capacity of cables of any number of conductors may be calculated from the rule that the total carrying capacity of all the conductors in a cable is approximately the same for any number of conductors. Actually this aggregate carrying capacity increases slightly as the number of conductors increases. Thus a two-conductor cable has about 8 per cent more and a four-conductor 8 per cent less "total cable temperature rise" than a three-conductor cable of the same total copper area and carrying the same aggregate current. Thus to determine the temperature rise for a given current per conductor for a cable of any number of conductors n greater than three we may safely proceed as follows. Determine the rise for a three-conductor cable of the same aggregate area and for a current per conductor of $3/n$ times the given value, and diminish this rise by 8 per cent of the "total cable rise" (that is exclusive of duct rise). Though these data apply to the total cable rise the sheath and insulation rises have quite different relative values for the different number of conductors.

TABLE VI

FLAT DUPLEX CABLES.

A—Temperature rise of conductor above sheath in degrees centigrade produced by 2/3 of the watts in table I, *i. e.*, the same current per conductor.

B—Temperature rise of sheath above cable surroundings in degrees centigrade produced by 2/3 of the watts in table I, *i. e.*, the same current per conductor.

Size	3/32-in. Paper		4/32-in. Paper		5/32-in. Paper		6/32-in. Paper	
	A	B	A	B	A	B	A	B
No 10 A.W.G.	6.3	13.3	7.5	11.2	8.5	10.3	9.3	9.3
" 4 "	4.9	14.	6.1	12.6	7.1	11.5	7.9	10.5
" 0 "	4.1	13.6	5.1	12.5	6.1	11.5	6.9	10.7
" 0000 "	3.6	13.4	4.6	12.4	5.5	11.6	6.4	10.9
350,000 C. M.	3.3	13.3	4.4	12.4	5.3	11.7	6.1	11.1
500,000 "	3.2	13.0	4.2	12.3	5.0	11.7	5.7	11.2
600,000 "	3.2	13.0	4.1	12.4	5.0	11.8	5.8	11.3
750,000 "	3.1	13.2	4.1	12.5	4.9	12.0	5.9	11.5

Type "H" Three-Conductor Cable. Table VII gives data for the type of cable proposed by Hochstadter and commonly called Hochstadter or type "H" cable. We are here concerned only with the three-conductor form. This consists of a cable in which all the insulation is placed on the conductors and which has a relatively thin covering of metal placed over the insulation on each conductor. This construction is used primarily for the purpose of elimination of electrical stresses in the electrically weak filler spaces. However, we are herein concerned only with the incidental though important effect of the metal covering or foil on carrying capacity. The metal covering as usually used brings the temperature of the entire surface of the insulation of each conductor nearly to the temperature of the sheath and thereby greatly reduces the temperature difference between conductor and sheath.

Table VII shows directly the maximum effect which can be gained by this construction, that is, on the basis of perfect thermal conductance of the foil but may be used as indicated below for convenient approximate calculation of temperature rise for practical conditions. Thus the temperature difference for the theoretically perfect condition may be found from Table VII and the temperature difference which would exist if the metal were not present may be calculated from methods described above. A known or assumed "efficiency" of the foil will then allow determination of the temperature for the practical condition. Thus for example consider 350,000-cm. conductor with 10/32-in. paper insulation. For 252 amperes, as given in Table I, the temperature difference given in table VII between conductor and sheath is 7.0 degrees. From table II, we find by interpolation, the temperature difference for that size of conductor and for a thickness of insulation of 10/32 in. between conductor and sheath (5 plus 5/32) to be 13.7 degrees. If we assume an effective thermal efficiency for the foil of 75 per cent, the temperature difference is found to be 7 plus $0.25 \times 6.7 = 8.7$ degrees. Actually, with practical cables the "effective thermal efficiency" of the foil is considerably greater than 75 per cent. Hence, in the absence of specific data it will usually be on the safe side to figure on that value.

TABLE VII.

THREE-CONDUCTOR HOCHSTADTER CABLES

A—Temperature rise of conductor above sheath in degrees centigrade produced by the watts in table 1.

B—Temperature rise of sheath above cable surroundings in degrees centigrade produced by the watts in table I.

Size	4/32-in.	Paper	6/32-in.	Paper	8/32-in.	Paper	10/32-in.	Paper	12/32-in.	Paper
	A	B	A	B	A	B	A	B	A	B
No. 4	4.4	15.3	6.4	12.7						
" 0	3.9	14.8	5.5	12.8	6.4	11.1	7.5	9.9	8.7	8.9
" 0000	3.4	14.8	4.9	13.0	6.0	11.7	7.2	10.5	8.4	9.6
350,000	3.2	14.7	4.7	13.1	5.8	11.9	7.0	10.8	8.2	9.7
500,000	3.1	14.5	4.5	13.1	5.6	12.0	6.8	11.1	8.1	10.2
600,000	3.1	14.5	4.5	13.3	5.5	12.2	6.8	11.2		
750,000	3.0	14.6	4.5	13.4	5.6	12.5	6.8	11.4		

Column A gives the temperature rise of conductor above sheath temperature that would be produced by the watts from table I on the assumption that the foil has infinite thermal conductance.

Concentric Cables. The combined carrying capacity of the conductor of concentric cables is nearly the same as for a single-conductor cable having the same total copper area and the same total insulation thickness. This is based on the assumption of equal current density in the different conductors. For more exact calculation the total "cable rise" found by the above rule should be multiplied by the following factors which are nearly independent of the size of conductor. (These factors apply to two-conductor concentric cables).

Insulation between conductors	3/32	4/32	5/32	6/32	8/32
Multiplying factor for total cable rise	0.97	0.96	0.95	0.94	0.92

Rope-Core Cables. The watts necessary to give a certain temperature rise of "hollow" or rope-core cables may be taken the same as for a solid conductor cable

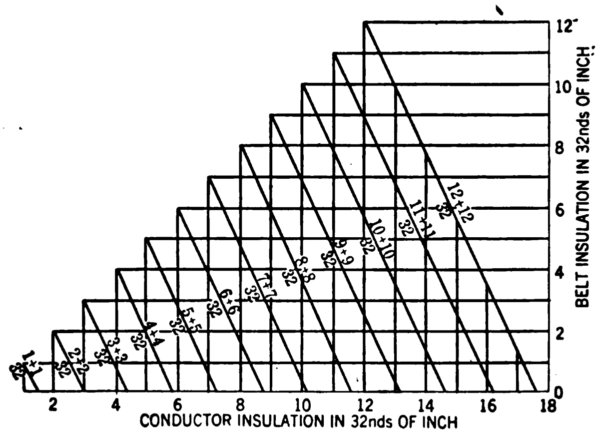

Fig. 2

having the same outside conductor diameter. The carrying capacity will then be proportional to the square root of the amount of copper in the conductor.

APPENDIX

The temperature of free air during the summer months may be as high as 40 deg. cent. Where the temperature of the air is not known this figure may be assumed as the base temperature in making calculations. If the cable is subjected to the direct rays of the sun, then 50 deg. cent. may be the figure used.

The base temperature of cables installed in the earth usually may be taken as 20 deg. cent. This is approximately the maximum temperature that the earth at conduit attains in this latitude. The base temperature of submarine cables is usually taken as 20 deg. cent.

Example No. 1. A three-conductor 350,000-cir. mil 6/32-in. plus 6/32-in. paper-insulated lead-covered cable is operating at 13.2 kv. It is freely suspended in air at an ambient temperature of 40 deg. cent. What is the allowable carrying capacity?

Allowable operating temperature (A. I. E. E.) 85 deg. cent. – 13.2 deg. cent. = 71.8 deg. cent.

Allowable cable rise 71.8 deg. cent. – 40 deg. cent. (Base Temp.) = 31.8 deg. cent.

From table I—6.75 watts (252 amperes) gives 25 deg. cent. cable rise for a 350,000-cir. mil cable insulated with 3/32-in. plus 3/32-in. paper.

From table II, the rises produced by 6.75 watts on a 350,000-cir. mil 6/32-in. plus 6/32-in. paper cable are:

Insulation rise.................. 15.2 deg. cent.
Sheath rise..................... 11.6 deg. cent.
Total cable rise produced by
6.75 watts.................. 26.8 deg. cent.

To produce 31.8 deg. cent rise would require $6.75 \times \frac{31.8}{26.8}$ watts.

The current to produce these watts as I^2R loss

$252 \times \sqrt{\frac{31.8}{26.8}}$ = The allowable carrying capacity = 274 amperes.

Example No. 2. What change in calculation would be necessary had the insulation been 8/32-in. plus 2/32-in.? The cable to operate at the same voltage.

See paragraph on unequal belt and conductor insulation. The insulation rise is the same as for a 5/32-in. plus 5/32-in. cable or........ 13.7 deg. cent.

The lead rise is the same as for a 6/32-in. plus 6/32-in. cable or........ 11.6 deg. cent.

The total cable rise is............. 25.3 deg. cent.

The allowable carrying capacity is

$252 \times \sqrt{\frac{31.8}{25.3}}$ .... 283 amperes

Example No. 3. What will be the carrying capacity of four three-conductor No. 0000 – 6/32-in. plus 6/32-in. V. C. cables to be installed in a conduit system containing no other cables? The cables operate at 15 kv.

Allowable operating temperature (A. I. E. E.) 75 deg. cent. – 15 deg. cent. = 60 deg. cent.

Maximum allowable rise of cable and conduit assuming 20 deg. cent. normal earth temperature = (60 deg. – 20 deg.) =..................... 40 deg. cent.

From table I—5.80 watts—(179 amperes) give 25 deg. cent. rise for No. 0000 – 3/32-in. plus 3/32-in. cable.

Table II gives 5.80 watts—(179 amperes) produce 15.0 deg. + 11.3 deg. =.......................... 26.3 deg. cent.

The total watts to be dissipated at this current equal 4 × 5.80 =....... 23.2

Assuming a heating constant of 1.0, the duct rise is 23.2 × 1.0 =....... 23.2 deg. cent.

One hundred seventy-nine (179)

amperes per conductor gives a total rise (cable and duct) 26.3 + 23.2 = . 49.5 deg. cent.

The carrying capacity for 40 deg. cent. rise (allowable rise) =

$$179 \times \sqrt{\frac{40}{49.5}} = \ldots\ldots\ldots\ldots\ldots\ldots \quad 161 \text{ amperes}$$

Example No. 4. Six three-conductor No. 0 – 4/32-in. plus 4/32-in. paper-insulated cables are operating in a conduit system. The cables operate at 2.3 kv. Measurement of the duct wall temperatures gives 45 deg. cent. The cables each carry 120 amperes per conductor. Is this a safe load?

The allowable operating temperature (A. I. E. E.) 85 deg. cent. – 2.3 deg. cent. = ... 82.7 deg. cent.

From tables I and II, 115 amperes give (12 + 12.9)

$$= 24.9 \text{ deg. cent. } 120 \text{ amperes give } \frac{120^2}{115^2} \times 24.9$$

= 27.0 deg. cent. cable rise. (27.0 deg. cent. + 45 deg. cent.) = 71.0 deg. cent is the temperature at which cables are operating with 120 amperes per conductor.

The cables are capable of carrying

$$120 \times \sqrt{\frac{\text{allowable rise}}{\text{rise produced by 120 amps.}}}$$

$$= 120 \times \sqrt{\frac{82.7 \text{ deg. cent.} - 20 \text{ deg. cent.}}{72.0 \text{ deg. cent.} - 20 \text{ deg. cent.}}}$$

= 132 amperes.

Example No. 5. Same as No. 3 except dielectric losses at 60 deg. cent. are known to be 0.26 watts per foot.

The total rise produced by 5.80 watts per foot = 49.5 (From problem No. 3).

$$\text{The rise produced by } 0.26 \text{ watts} = 49.5 \times \frac{0.26}{5.8}$$

= 2.2 deg. cent.

This allows 40 – 2.2 = 37.8 deg. cent. as rise to be produced by $I^2 R$ loss.

$$\text{The carrying capacity} = 179 \times \sqrt{\frac{37.8}{49.5}}$$

= 156 amperes.

The Chart. The chart given here is really the solution of problems in the same class as Example No. 3, *i. e.*, the solution of carrying capacity problems of paper and V. C. cables installed in conduits where no measurement of duct wall temperature is made. The chart will give results about as accurately as calculation from the tables.

The method of using the chart is as follows: In the upper right hand find the intersection of the size of conductor and insulation thickness. From the point of intersection follow a horizontal line to the upper left-hand corner of the chart to the line giving the factor "number of cables times duct (heating) constant."

From the intersection of these lines follow the vertical line to the intersection with the lines marked "allowable temperature rise." This is the allowable operating temperature minus the normal earth temperature.

Next follow a horizontal line to the intersection of the lines marked number of cables times duct (heating) constant.

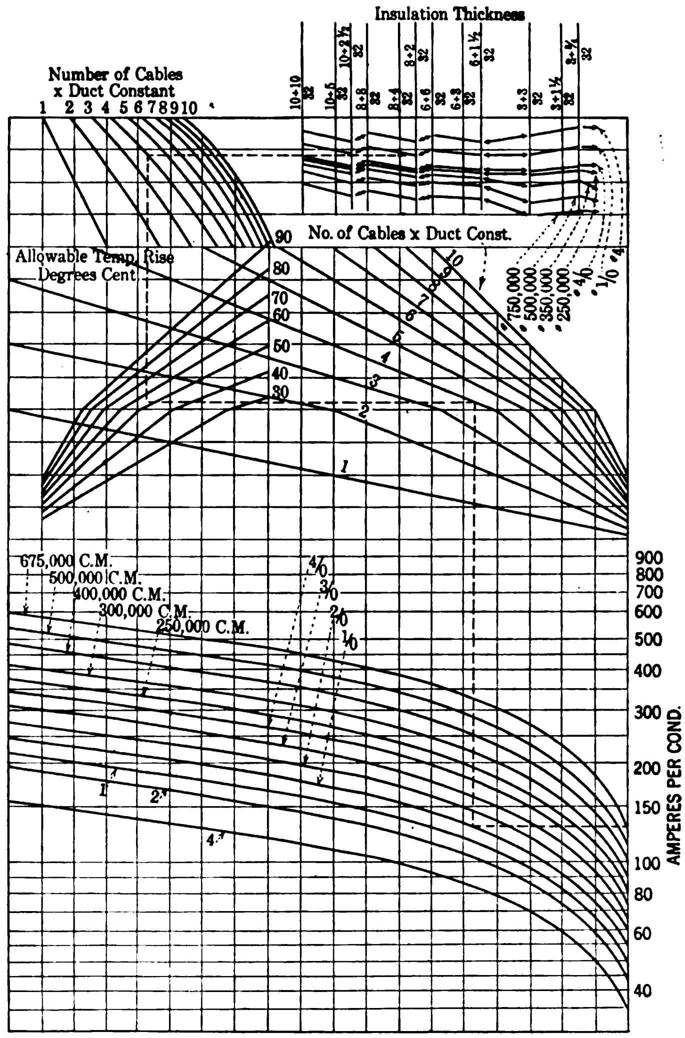

Fig. 3—Current-Carrying Capacity of Three-Conductor Underground Cables
Round and Sector, Paper and Varnished Cloth

Follow a vertical line down to the intersection with the size of conductor. Directly opposite this will be found the amperes per conductor.

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CORRESPONDENCE

TERMINOLOGY IN REGARD TO REACTIVE COMPONENT

To the Editor:

Recently a great deal has been written and spoken concerning power factor and allied subjects. The A. I. E. E., various commercial engineering societies, the technical press and individual organizations have devoted much attention to these subjects.

In following this discussion one cannot but be impressed by the wide variance in terminology, particularly when the reactive component of the kv-a. is involved. The following is a list of terms which the writer has happened upon in recent papers read before the A. I. E. E. and in recent numbers of the *Electrical World*.

Referring to the Reactive Component:

Reactive volt-amperes.
Reactive power.
Wattless power.
Imaginary power.
Apparent reactive power.
Reactive kilowatts.
Reactive kilowatt-hours.
Kilo-reactive-watt-hours.
Reactive kilovolt-ampere-hours.

Referring to Volt-Amperes or Volt-Ampere-Hours:

Apparent power.
Apparent energy.
Kilovolt amperes.
Total vector watt-hours.
Kilovolt-ampere-hours.

Definition 24 of the Standardization Rules of the A. I. E. E. defines "Reactive Volt-Amperes". The term "reactive power" is not used in the rules. In the recent report of the Special Joint Committee on the Determination of Power Factor in Polyphase Circuits and the accompanying papers, the expression "reactive power" was used much more frequently than "reactive volt-amperes". This term is consistent with and completes what might be called the "power triangle", of which apparent power is the hypotenuse, true power is the base, and reactive power is the altitude. Furthermore, from a theoretical point of view "reactive power" may be justified by an analysis of its physical significance as the rate at which energy is stored in or released from the magnetic field, although its measurement by the "reactive volt-ammeter" will be only approximate, except when the voltage and current are sinusoidal and the circuit constants do not vary cyclically (see article on " Reactive Power and Unbalanced Circuits" by Prof. Waldo V. Lyon, *Electrical World*, June 19, 1920, page 1417).

When the terminology is extended, and it becomes necessary to use a unit involving time, the expression "reactive kilowatt-hours" seems to the writer to be a misnomer. Also a unit should be definite and clearly understood, without any modifying adjectives.

More and more power companies are adopting power factor rates necessitating the use of integrating meters which record the reactive component kv-a. hours. Various companies have recently issued rate schedules in which the expressions "reactive kilowatt-hours", "kilo-reactive-watt-hours" (abbreviated k. r. w-hr.) etc., are used. Standardization of terms is much needed.

The writer would point out the desirability of coining or adopting an entirely new term for the reactive volt-amperes. A simple word with a single letter abbreviation would greatly simplify the present involved terminology. For illustration suppose we use the word "Blank", abbreviated "b", for the unit for expressing reactive power. The so-called power triangle will then have kv-a. for the hypotenuse, kw. for the base and "kb." for the altitude. "Kb-hr." then corresponds to "kw-hr.", and a meter which integrates the reactive component of the kilovolt-amperes then becomes simply a "blank-hour" meter, corresponding to a watt-hour meter.

The difficulties involved in defining and measuring such a unit are no greater than, and in fact are involved in and in a sense precede, the difficulties of defining and measuring power factor.

In view of these facts it seems highly desirable that the Standards Committee of the A. I. E. E., perhaps in conjunction with the N. E. L. A., or the Special Power Factor Committee, should select and define suitable terms for these conceptions.

RALPH L. THOMAS
Pennsylvania Water & Power Co., Baltimore.

A-C. VERSUS D-C. ARC WELDING

To the Editor:

With reference to the correspondence appearing on page 647 of the July JOURNAL, I wish to say that I personally am opposed to becoming a party to purely commercialized arguments, and for this reason, I will not mention the name of the company which manufactured the arc welding transformers submitted to us for test purposes, but will simply outline certain test data obtained thereon:

Primary			Secondary			Transformer	
Volts	Amp.	Kw.	Volts	Amp.	Kw.	Efficiency	Power Factor
437	39.2	3.6	20	112	2.24	62.5%	21.0%
436	44.4	4.96	20	128	2.56	51.5%	25.6%
440	49.5	5.56	21	150	3.16	56.5%	25.6%
396	48.0	5.85	20	170	3.47	59.5%	30.8%

The above data were obtained when the operator was using standard welding wire having a light coating throughout its entire length on approximately one-half of its surface.

Although the power factor of the arc itself is approximately 88 to 92 per cent, according to good authorities, nevertheless the power factor of the welding trans-

former in which we are actually interested is much below this value as indicated by the above table. This does not mean that the transformer is poorly designed but is simply a recognition of the fact that this characteristic must be incorporated if the transformer is to be satisfactory for lightly coated metallic electrode welding.

Based upon the *no load losses* in addition to the above obtained data, and also including the cost of the partially coated electrode material, the operating cost data, including power, wire and labor were prepared as presented in my paper.

Some individuals evidently fail to realize that the cost of welding wire is even more important than the cost of power in determining the operating cost of arc welding, due to the fact that the efficiency of the transformer is practically on a par with that of the overall efficiency of a modern single-operator inherently regulating motor-generator set, whereas the power factor of the transformer is materially below that of a modern induction motor used as part of the interconnected single-operator outfit. For example, under normal full load conditions, the power factor of the induction motor will be approximately 90 per cent, whereas the no load power factor, namely when the motor-generator set is running light, will be approximately 48 per cent. If the welding operator uses power 65 per cent of the time, it is easy to calculate that the average all day power factor is approximately 75 per cent, whereas if the operator works 80 per cent of the time, the average all day power factor is approximately 81½ per cent, al of which (including no load power factor) are apprecil ably above the tabulated test data for the a-c. welding transformer.

I would refer those who are interested in a further discussion of the power factor of the a-c. transformer to an article on page 233 of the *Electrical World* for February 1, 1919.

A. M. Candy, General Engineer
Westinghouse Elec. & Mfg. Co

NOTE ON SPEED OF FLASHING OF INCANDESCENT SIGNAL LAMPS

A portion of a study of the theory of signaling units involving incandescent lamps, which was undertaken in response to a request from the National Research Council and the U. S. Signal Corps for the development of a unit for use in daylight signaling is herein given.

Filament Characteristics Involved. Various factors involving speed where the telegraphic dot and dash signals are produced by the flashing of an incandescent lamp, are discussed in a broad way in a contrast of tungsten with carbon for filament material. Most important are (1) the change in resistance with change in temperature, (2) the quantity of energy required to heat the filament through a given temperature range, (3) the total emissive power of the filament material, (4) the maximum temperature of a flash, and (5) the efficiency of the radiation in producing vision. For lamps of equal voltage, life and luminous flux, tungsten is favored during the heating portion of a flash by a factor of six or seven.

Observed Speeds and Their Comparison with Expected Values. A photometric method of studying the performance of lamps on flashing is described and the results obtained with various lamps are presented. These are compared with computed values based on steady current measurements and the supposition that a lamp filament on heating or cooling passes through a succession of steady states. The agreement is quite satisfactory, when there is excepted the case of a filament immersed in hydrogen, where the discrepancy may be ascribed to ionization effects.

Speed Functions. It is further shown that a simple function involving only steady current measurements of wattage, resistance and temperature in the neighborhood of the maximum temperature of a flash, together with the thermal capacity of the filament, will serve quite accurately in rating various lamps as to their flashing speeds.

Some Fundamental Generalizations.

(1) The time required for a filament to heat to approximately its maximum brightness exceeds greatly the time required in cooling to effectively zero brightness.

(2) The higher the maximum temperature of a flash, the greater is the speed of the flash.

(3) The smaller the filament, the greater is the speed of the flash.

(4) The less the resistance in a circuit external to the flashing lamp, the greater is the speed of the flash.

(5) The speed of flashing for a given filament at a given temperature in various atmospheres—including in vacuo—is the greater, the greater the gas loss.

(6) For lamps of the same open filament construction in various atmospheres, such that they possess the same luminous flux and the same average life at the same fixed voltage, the speed of flashing is the greater, the greater the gas loss.

Ribbon Versus Wire Filaments. A contrast of a lamp containing a ribbon filament in argon as proposed by the Nela Research Laboratory in response to the request noted above, with that lamp which was its nearest competitor indicated speeds and efficiencies in favor of the former lamp of the order respectively of 1.6 and 1.25.—A. G. Worthing, in *Journal* of the Franklin Institute.

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with which is incorporated the PROCEEDINGS of the A. I. E. E.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

FUTURE INSTITUTE MEETINGS

OCTOBER MEETING

The first regular Fall meeting of the Institute will be held in Philadelphia October 8, 1920. The tentative program, to which some additions will probably be made, includes an afternoon and an evening session, with an informal subscription dinner between the sessions.

Two papers will be presented at the afternoon session, as follows:

Economic Study of Secondary Distribution, by P. O. Reyneau and H. P. Seelye, Detroit Edison Co.

Electrical Demand Measurements, by P. A. Borden, Ontario Power Commission.

The evening session will be a special meeting to commemorate the hundredth anniversary of the discoveries of Arago, Ampere, Davy, and Oersted. The principal speakers will be Prof. Elihu Thomson and Prof. M. I. Pupin. Demonstration of some of the original experiments will be made. Addresses by other speakers will be announced later.

NOVEMBER MEETING

The November meeting will be held in Chicago on November 12, 1920, and will be under the auspices of the Protective Devices Committee. The principal paper of the meeting will be by Mr. D. W. Roper, Chairman of the Committee, on the subject of Lightning Protection.

A. I. E. E. DIRECTORS MEETING

AUGUST 12, 1920

The first meeting of the Board of Directors of the American Institute of Electrical Engineers for the administrative year beginning August 1, 1920, was held at Institute headquarters, New York, on Thursday, August 12, 1920 at 3:00 p. m.

There were present: President A. W. Berresford, Milwaukee; Past Presidents Calvert Townley and C. A. Adams, New York; Vice-Presidents Charles S. Ruffner, New York, Charles Robbins, Pittsburgh, L. T. Robinson, C. S. McDowell, Schenectady, E. H. Martindale, Cleveland; Managers, Wm. A. Del Mar, W. I. Slichter, L. E. Imlay, E. B. Craft, New York, Wilfred Sykes, F. D. Newbury, Pittsburgh, G. Faccioli, Pittsfield, H. B. Smith, Worcester; Treasurer, George A. Hamilton, Elizabeth, N. J.; H. E. Farrer, representing Secretary F. L. Hutchinson, New York.

Resolutions were adopted authorizing the appointment of a new standing committee, on "Coordination of Institute Activities," to replace the former Board's Committee on Technical Activities, which was authorized by the Board of Directors May 17, 1918, for the purpose of stimulating and coordinating the activities of technical committees; the new committee to fill a need for a committee of much broader scope, on coordination of Institute activities in general, to which might be referred, for recommendation to the Board, questions of Institute procedure and policy.

President Berresford announced the appointment of committees for the administrative year commencing August 1, 1920, as published elsewhere in this issue of the JOURNAL.

In accordance with the by-laws of the Edison Medal Committee, the Board elected from its own membership Messrs. W. I. Slichter, L. E. Imlay, and F. D. Newbury, to serve upon the Committee for the term of two years ending July 31, 1922.

The following Local Honorary Secretaries, whose terms expired July 31, 1920, were reappointed by the Board for the term of two years ending July 31, 1922: L. A. Herdt, Canada; A. S. Garfield, France; Harry P. Gibbs, India; T. P. Strickland, New South Wales; Robert J. Scott, New Zealand; W. G. T. Goodman, South Australia; John W. Kirkland, South Africa.

The action of the Finance Committee in approving monthly bills amounting to $21,592.40 was confirmed.

Reports were presented of meetings of the Board of Examiners held on July 26 and August 9, 1920; and the actions taken on applications at those meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 28 Students were ordered enrolled; 173 applicants were elected to the grade of Associate; 11 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 33 applicants were transferred to the grade of Member; 6 applicants were transferred to the grade of Fellow.

The Board authorized the formation of an Institute Section at Akron, Ohio, subject to the approval of the Sections Committee.

Resolutions were adopted accepting an invitation to become a Charter Member of The Federated American Engineering Societies and to appoint delegates to the first meeting of the American Engineering Council, to be held during the Fall of this year. These resolutions appear elsewhere in this issue of the JOURNAL.

In addition to these actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the JOURNAL under suitable headings.

SIXTH NATIONAL CHEMICAL EXPOSITION

The Sixth National Exposition of Chemical Industries will be held in Grand Central Palace, New York City, Sept. 20 to Sept. 25, inclusive. The program that has been arranged is in keeping with the progress of the industry, which is evidenced

by more than 400 different exhibits securing space this year. The program calls for five symposiums, for which the speakers are among the best known in the industrial and chemical engineering worlds. The symposiums will be on Fuel Economy, Industrial Management, Materials Handling, Chemical Engineering, and Ceramics. Motion pictures also will greatly aid in placing the importance of the chemical industry before the public.

Dr. Charles H. Herty, chairman of the Advisory Committee of the exposition, will open the display at 8 o'clock on the evening of Monday, Sept. 20. Charles L. Reese, who will talk on "Cooperation in the Industries," and other speakers will follow. The motion picture program for the opening night includes two subjects, "The U. S. Ammonium Nitrate Plant No. 2 at Muscle Shoals," by courtesy of Dwight P. Robinson & Co., and "Modern Packaging Methods," by courtesy of the Pneumatic Scale Corporation. Beginning Tuesday, afternoon and evening sessions will be held in order to carry out the big program.

I. E. S. CONVENTION AT CLEVELAND

As has already been announced, the date for the next annual convention of the Illuminating Engineering Society, originally set for September 27-30, has been changed to October 4-7. The change was made to avoid conflict with the American Legion Convention to be held in Cleveland the last week in September it being felt that the gathering together, in one city and at the same time, of the two organizations, would cause Cleveland's visitors to suffer inconveniences.

It is the aim of the committee to make this convention carry a popular appeal not only to technical men but to all those in any way interested in illumination.

The committee in charge of arrangements is as follows: General Convention Committee, J. E. North, Cleveland Electric Illuminating Company, chairman, W. M. Skiff, National Lamp Works, vice-chairman; Reception Committee, G. E. Miller, Cleveland Illuminating Co., chairman; Publicity Committee, H. S. Greene, National Carbon Co., chairman; Entertainment Committee, J. M. Smith, Ivanhoe-Regent Works, chairman; Finance Committee, George S. Milner Erner Electric Co., chairman; Hotel Committee, A. M. Collins, Western Electric Co., chairman; Attendance Committee, G. S. Black, Cleveland Engineering Society, chairman; Registration Committee, J. L. Wolf, Builders Exchange, chairman.

CHICAGO SECTION OF AMERICAN WELDING SOCIETY ORGANIZED

At a meeting of members of the welding trade in Chicago, held in the rooms of the Western Society of Engineers, on Tuesday Evening, August 3rd, a Chicago Section of the American Welding Society was organized. There were about seventy-five in attendance, representing many railroads terminating in Chicago and also many of the larger local industries.

Election was held of officers and directors. Meetings will be held on the second Tuesday of each month in the rooms of the Western Society of Engineers, and those interested in the subject of Aurogenous welding, by all methods, are invited to attend. The Secy-Treas. is L. B. Mackenzie, 608 S. Dearborn St., Chicago.

HYDROELECTRIC DEVELOPMENT IN CEYLON

The proposed electrification of the industries of the island of Ceylon, and a partial transformation of the transportation systems from steam to electricity, offer a large opportunity in hydroelectric development today. The proposed scheme, developed by the Public Works Department, has been under consideration for a number of years past. Definite action was delayed because of the war, but it is expected now that arrangements will go forward rapidly for the early initiation of the work proposed. Recently at the request of the Ceylon Government Mr. J. W. Meares, the Electrical Advisor to the Government of India, made extensive investigations of the island's hydroelectric resources. Ceylon newspapers printed the gist of his report in various articles, a few extracts from which follow:

The report of Mr. J. W. Meares, M. Inst. C. E., M. I. E. E., Electrical Advisor to the Government of India, who was lent to Ceylon to report on our own hydroelectric schemes, has been published by the Government of India, Calcutta, and from it we place the following information before the reader. The report is on the Laxapana-Aberdeen project only.

The first part of this report gives general data regarding the available water in the area, *the possibilities of storage*, the order in which the four successive stages of development should be undertaken, and the power available.

The second part deals with the layout of the combined scheme calling attention to a number of points which must be borne in mind when designing it in detail.

The third part deals with the initial development of the scheme and touches upon the question of the subsequent extensions.

The fourth part goes into the utilization and price of the power, which are the prime factors in deciding if it shall be undertaken.

The fifth part deals on broad lines with the agency for carrying out the project.

It may be stated here that Ceylon has far *more water power than it can ever use* unless industries are specially started to turn this natural wealth into hard cash. The industries report gives outline figures showing some 264,000 hydroelectric horse power continuously available, and with additional storages not examined this would doubtless be considerably increased. Some of these sites were visited by the writer, and others were examined from the very excellent contour maps of Ceylon she is fortunate in possessing. Thus the Kotwalia Oya (a tributary of the Mahaveli Ganga) could be developed either at the St. Clair Falls, Talawakelle, where a flow of some 250 cusecs(cubic feet per second) and a fall of 800 feet would give over 16,000 e. h. p. continuously; or near Somerset, Gampola, where some 500 cusecs are always available with a fall of over 500 feet giving a further 20,000 e. h. p. and over. This last project is a meritorious one and was visited; but its possibilities are only a fraction of those of Laxapana-Aberdeen while the cost of development would be higher.

. . . . it (Laxapana-Aberdeen project) is an exceptionally favorable one in all the essential points, in that a large constant flow is assured, storage can be provided, two separate rivers can be combined, a large head is available, the locality is accessible and healthful, and the transmission distances are reasonable.

. . . . Briefly the project involves the harnessing of the Kenelgomu Oya and the Maskeliya Oya above their junction, by leading their waters in channels to a point where a fall of not far short of 2,000 feet can be obtained, and then by means of pipes leading this supply to Pelton wheels at the foot of the fall. The water that would ordinarily run to waste will be impounded in reservoirs above the off-take.

The Laxapana-Aberdeen project is recommended—

The continuous (24 hour) power available is—

First stage	20,000 e. h. p.
Second stage	37,000 e. h. p.
Third stage	64,000 e. h. p.
Fourth stage	96,000 e. h. p.

or 620 million units per annum.

The working head is over 1900 feet.

To get ultimate economy the scheme must be designed for the full development; and certain parts such as the channels must be built for the complete "first stage."

Statistics of power now used are quoted and the probable requirements for the tea industry and the *electrification of suburban railways* are estimated. The probable average cost per unit generated at the power house is found to be well under two cents initially and will be far lower hereafter.

Suggestions are made as to the rates at which power can be sold for various places and industries so as to give a reasonable return on capital. Recommendations are made as to the purchase of existing installations and as to the method of carrying out the Laxapana-Aberdeen project and working it thereafter.

The adoption of British Standard pressures and frequencies and, if possible, British plant, is urged.

The chief industry of Ceylon is agriculture—tea, coconuts, rubber, cinnamon, tobacco, coffee, and cinchona are the principal products. The island is one of the greatest tea-producing countries in the world, and tea plantations make up the most prominent feature of the island now. To make way for them most of the forests of rare and valuable trees are being destroyed. Ceylon has long been noted for being a garden place of the world, with a great variety of ferns and flowers remarkable for their beauty.

Mr. Meares' report gives the following estimate as to the total requirements of the tea industry:

The annual output of Ceylon tea is 200,000,000 lb. . . . power for driving the machinery requires 0.25 units per lb. of tea which comes to 58,000,000 units. Manufactories, however, will continue to use their own water power so that the actual requirements may be given as 30,000,000 units. If used for 3650 hours per annum ten hours a day, this means a rate of 8200 kilowatts at the factories or about 10,000 kilowatts more or less at the power station eventually. The "peak load" would be somewhat higher but not much. For drying purposes 200,000,000 pounds at 1.67 units per lb. comes to some 330,000,000 units as a maximum. One may reasonably look forward to 150,000,000 units being used within a reasonable time. If used for 2900 hours per annum, (eight hours a day) this means a rate of 51,600 kilowatts at the factories or say 60,000 kilowatts at the power station. A favorable factor is that the load, being largely non-inductive, would have a good power factor. Combining this, the total in sight comes to 180,000,000 units and 70,000 kilowatts installed to meet it. The load factor of the tea industry comes then to 34 per cent only.

Mining is another industry of Ceylon. The island is famed for its precious stones, especially rubies and sapphires. Plumbago mines are also of note.

Colombo, the capital of Ceylon (213,396—population in 1911) will probably be the center of electrification projects. Suburban railways, and transmission lines to factories and power plants, will be in the electrification scheme. The electrification of all the island's railroads is not planned, however.

The electrification of the main lines of Ceylon is out of the question as a commercial proposition. Electrification will only pay for the steep ghat section and suburban traffic. The latter covers the coastline to Panadura, the line to Negombo and the Kelani Valley line.

For domestic use in Colombo and other cities the transmitted power will also be of great value. The report advises that the whole problem of water-borne sewage would be simplified, with great saving, by the use of motor-driven, centrifugal sewage pumps; and that suburban traffic could be eased by the extension of electric tramways.

The whole island is within the use of transmission distance of the Laxapana-Aberdeen scheme, but at present the demand is great enough only in the Western and Central Provinces to justify the cost of transmission. Development within the demand, however, will be well worth while; and after completion of the main electrification project expansion can take place as required.

ENGINEERING FOUNDATION

A NEW FORM OF WEIR

A new form of weir and a simple, straight-line formula have been devised by Clemens Herschel, Past-President, Am. Soc. C. E., for gaging the flow of water in open channels. This weir and the accompanying formula are results of experiments made by Mr. Herschel with the support of Engineering Foundation, at the laboratory of Massachusetts Institute of Technology. A report of the experiments was presented in the form of a paper to the American Society of Mechanical Engineers. and was printed in full in "Mechanical Engineering" for February, 1920, the Journal of the American Society of Mechanical Engineers. See also *Engineering News-Records*, issue of April 8, 1920, pages 710-712. The complete paper has been issued as Number 4 in the "Reprint" series of Engineering Foundation. Copies can be had by members on application to office of Engineering Foundation; non-members may obtain copies at the rate of 35 cents each.

COMMITTEE ON HYDRAULIC RESEARCH

A committee on Hydraulic Research has been appointed by Engineering Foundation. The committee will endeavor to formulate problems to which it may be possible for Engineering Foundation to devote some of its efforts. It will also endeavor to collect information about existing hydraulic laboratories and other places in which hydraulic experiments can be conducted. Mr. J. Waldo Smith and Mr. Silas H. Woodard have consented to serve as the committee. Members of the Board are requested to assist with suggestions and information.

FEDERATED AMERICAN ENGINEERING SOCIETIES

ADDITIONAL SOCIETY RATIFICATIONS

At the meeting of the Board of Directors of the American Institute of Electrical Engineers held in New York on August 12, 1920, the following resolutions to become a charter member of The Federated American Engineering Societies were unanimously adopted;

WHEREAS, under date of July 26, 1920, the Joint Conference Committee of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, acting as the Ad Interim Committee in accordance with the authorization of the Organizing Conference held in Washington, D. C., June 3-4, 1920, extended to the American Institute of Electrical Engineers an invitation to become a Charter Member of the Federated American Engineering Societies, and to appoint delegates to the first meeting of the American Engineering Council; and

WHEREAS, the American Institute of Electrical Engineers recognizes the pressing necessity for such an organization, is in full accord with its objects, and approves of the theory of the proposed organization and the method by which it is to be constituted, be it

RESOLVED: That the American Institute of Electrical Engineers accepts the invitation extended to it to become a Charter Member of the Federated American Engineering Societies, and pledges its hearty cooperation in the work thereof; and further be it

RESOLVED: That the President be instructed to present to the Board of Directors at its October meeting a suggested list of delegates to the first meeting of the American Engineering Council, which is proposed to be held during the Fall of the present year.

REPRESENTATION OF LOCAL ORGANIZATIONS

In the August JOURNAL, the Joint Conference Committee interpreted the Constitution and By-Laws concerning the relation between local and state affiliations as regards membership in The Federated American Engineering Societies. The Committee is in receipt of communications relative to the interpretation of the Constitution and By-Laws as they apply

solely to the membership of local engineering and allied technical organizations in The Federated American Engineering Societies.

It is contended that a local affiliation could not claim representation on the basis of its members who belong to the national societies that had joined the organization directly, and would not be required to pay dues on that account. The Constitution states in Article IV—Section 3

provided that in the determination of the representation of local, state and regional organizations and affiliations no count shall be taken of any organization which is represented individually or through another local, state or regional organization or affiliation;

That is to say, if there were in a community five local engineering and allied technical organizations all in a local affiliation, and one of them was a member of The Federated American Engineering Societies, then the remaining four societies would be entitled to representation as an affiliation in The Federated American Engineering Societies, through its membership as a local affiliation, on the basis of the aggregate membership—less the membership of the local organization that already held membership in The Federated American Engineering Societies, or each of the four organizations could individually become a member of The Federated American Engineering Societies.

THE LARGEST AMERICAN ENGINEERING ORGANIZATION

It is a common failing to refer to The Federated American Engineering Societies as a "proposed" organization. Attention is called to the fact that The Federated American Engineering Societies is in actual existence and at present its membership consists of The American Society of Mechanical Engineers, the Detroit Engineering Society, the Technical Club of Dallas and the American Institute of Electrical Engineers. It is not a question whether the organization will be formed; the Federated American Engineering Societies already is the largest engineering organization in this country.

MEMBERSHIP REQUIREMENTS

There still seems to be uncertainty in the minds of some as to the eligibility of organizations for membership. The following provision is in Chapter I, Section I of the By-Laws of The Federated American Engineering Societies:

Any society or organization of the engineering or allied technical professions whose chief object is the advancement of the knowledge and practise of engineering or the application of allied science, and which is not organized for commercial purposes, is eligible for membership.

This provision is in no sense intended to make the organization exclusive, but merely to make it inclusive of all those engineers and allied technologists who are members of organizations not formed for commercial purposes and whose chief aim is the advancement of the knowledge and practise of engineering. The tendency of the times is to raise the standard of engineering requirements and this is augmented by the constantly increasing influence of the technical schools. The four Founder Societies have maintained high standards for membership and of late their requirements have been increased, and yet, in spite of this, these societies have shown an increasing growth in membership.

ADVANTAGE OF COMBINED PRESTIGE

The Federated American Engineering Societies will have the advantage of the combined prestige of all its Member-Societies and will, therefore, have a greater standing than any individual society. It was for the purpose of securing this advantage that the organization was made one of societies and not of individuals. An individual can only become connected with the work of the organization through his membership in a national, local, state or regional engineering or allied technical organization; since there are no individual memberships in The Federated American Engineering Societies, therefore, individuals must join these organizations in order to be identified with its work. The Federated American Engineering Societies will be a powerful, dominant organization. No engineering or allied technical organization can afford to reject the opportunity for affiliation; it is an obligation to the profession to be so affiliated.

ORGANIZATION IS REPRESENTATIVE AND DEMOCRATIC

The form of organization of The Federated American Engineering Societies is analogous to that of the Federal Government in which the individual citizen is represented first in the local government, then in the state, and finally in the national government; he does not have individual representation in the national government, but because he does not have this representation it cannot be construed that the organization is undemocratic.

It must be quite evident to any one who would start a new engineering organization, and it is the common belief that there are already too many in existence, that the organization would be without prestige, and, therefore, without the standing it would have with the prestige The Federated American Engineering Societies will possess. It is felt that the individual will be just as responsive through his local organization, and perhaps more so, than he would be if he held an individual membership. It is the experience of the national engineering societies that the individual engineer is much more responsive to the work of the society where it has local and professional sections than where there are no such sections. While The Federated American Engineering Societies is an organization of societies, this does not prevent the individual member of any of the Member-Soceities from communicating directly with the secretary or other executive officers of the organization. The governing body is controlled by the representatives of the Member-Societies; the district members of its Executive Board are elected by the votes of the representatives from each district.

Notwithstanding the vagueness of the word democracy, the Joint Conference is firmly of the opinion that The Federated American Engineering Societies is truly a democratic organization because it represents the individual engineer and allied technologist.

THE MINNESOTA FEDERATION

The movement to federate the engineer and the allied technologist is again to bear fruit. The Committee is gratified to observe that engineers and architects from all parts of the State of Minnesota met at Duluth recently and took the first steps toward the formation of a state federation of engineers and architects. It is presumed that this organization will become a member of The Federated American Engineering Societies and it is hoped that the action in Minnesota will be followed by similar action in other states; only through united action of this character can the full strength of the solidarity of the engineering and the allied technical professions be realized.

CURRENT ENGINEERING TOPICS

ORGANIZATION AND STATUS OF FEDERAL POWER COMMISSION

The Federal Power Commission which was created to administer the Water Power Act, which was passed and signed by the President in the closing days of the last Congress, has been organized along the following lines: engineering, accounting, statistical, regulatory, licensing, legal and operation. It is apparent that the engineering division will be the most important because it will make general investigation of the electric power industry, power sites, costs and development. This division will have to report the results of these examinations to Congress preparatory to construction by the U. S.; will prepare plans for the development of streams upon which appli-

cation for licenses are made; will consider construction plans proposed by licenses; will make physical valuation of property in rate-making proceedings, and when existing plants are brought under the Act it will determine the necessary repairs, maintenance charges, develop operating rules, and determine adequate depreciation reserves. All of this work will come under the immediate charge of Mr. O. C. Merrill, who will act as chief engineer.

The actual work of the Commission has been somewhat barred because the comptroller of the Treasury has ruled that under the terms of the act, there is no money available to pay the required personnel. This means that the personnel will have to be assigned to the Commission by the various Departments until such time as appropriations can be made to pay for the required assistance.

So far Lieut. Col. William Kelley of the Engineers Corps, has been assigned to the Commission as engineer officer and Major L. W. Call has been assigned from the Judge Advocate General's Office as chief counsel.

It was one of the chief duties of the new Commission to formulate regulations that would make the applications for water power privileges valid. These regulations were drawn up by the Secretary and all interested Government Departments and outside organizations were invited to send their representatives to a Washington conference on August 12th for the purpose of discussion in making further recommendations. This meeting was followed by another conference on the 13th with representatives of interested financial institutions, so that their recommendations could also be considered before the application was put into final form. It is contemplated that the application blanks in final form will be completed and ready for use early in September.

District offices of the Commission have been opened at St. Paul and St. Louis in the local offices of the Corps of Engineers. This is for the convenience of the applicants in the Middle West. Similar district offices have been opened in Denver and San Francisco in the legal offices of the Forest Service for the convenience of the Western applicants.

CHEMICAL WARFARE SERVICE

When the Army Reorganization Bill passed the last Congress, it provided for a separate Chemical Warfare Service. The transfer of General A. A. Fries and Colonel Earle J. Atkisson from the Corps of Engineers to the command of this Service has now been completed and they are in the process of building up their organization under the terms of the Act.

In order to bring the Service up to full strength there are something over twenty commissions that will have to be awarded this Fall. In an effort to arouse interest in securing these commissions the heads of twenty-five technical colleges have been apprised of the conditions, in the hope that some of their students will apply for the vacancies. A number of West Point cadets have expressed their interest in this Service and requested commissions therein.

For the purpose of stimulating outside research on the problems coming under the jurisdiction of Chemical Warfare, General Fries plans to request a cooperative agreement with interested technical societies. In this way he hopes to keep the profession interested in the work of the Service. It is apparent that sufficient appropriations cannot be secured now to conduct the volume of research work which should be in progress and since other countries are devoting so much attention to this kind of warfare, it appears necessary to get the outside help.

NEW YORK CITY ESTABLISHES PENSION SYSTEM

Through an enabling Act of the 1920 Legislature a pension system was created in New York City, the support of which is to be shared equally between the City and its employees. In the case of the administrative and technical forces, it provides for optional retirement at the age of sixty and mandatory retirement at seventy, with a pension allowance at the rate of one-seventieth of the average salary for the last ten years of service, for each year of service. It is thus made practicable for an employee to retire on a substantial annuity at a period in his life when he can really enjoy it. The contributions to this fund are graded according to class of service, age, and time of entrance into the City service, and range from about 4 upwards to a little over 7 per cent of the employee's salary. In case of withdrawal from the service for any cause, all contributions to this fund on the part of the employee are repaid together with interest at the rate of 4 per cent. Incidental features of the plan include pensions for disability, life insurance to the extent of one-half a year's salary, and pension to dependents in case of the employee being killed while in the performance of duty. These latter benefits are paid for wholly by the City, which also assumes the burden of financing the operation of the fund for those now in the service up to October 1, 1921, or such previous date as they may elect to avail themselves of it. Acceptance of the plan is optional on the part of present employees but is mandatory upon those who join the service after October 1, 1920, when the system goes into effect.

NATIONAL RESEARCH COUNCIL

The National Research Council has elected the following chairmen of its various divisions for the year beginning July 1, 1920:

Division of Foreign Relations, George E. Hale, Director, Mt. Wilson Observatory, Carnegie Institution of Washington; Government Division, Charles D. Walcott, Secretary of the Smithsonian Institution, and President of the National Academy of Sciences; Division of States Relation, John C. Merriam, Professor of Paleontology, University of California and President-elect of the Carnegie Institution of Washington; Division of Educational Relations, Vernon Kellogg, Professor of Entomology, Stanford University and Permanent Secretary of the National Research Council; Division of Industrial Relations, Harrison E. Howe; Research Information Service, Robert M. Yerkes; Division of Physical Sciences, Augustus Trowbridge, Professor of Physics, Princeton University; Division of Engineering, Comfort A. Adams, Lawrence Professor of Engineering, Harvard University; Division of Chemistry and Chemical Technology, Frederick G. Cottrell, Director of the Bureau of Mines; Division of Geology and Geography, E. B. Mathews, Professor of Minerology and Petrography, Johns Hopkins University; Division of Medical Sciences, George W. McCoy, Director of the U. S. Hygienic Laboratory since 1915; Division of Biology and Agriculture, C. E. McClung, Professor of Zoology, University of Pennsylvania; and Division of Anthropology and Psychology Clark Wissler, Curator of Anthropology, American Museum of Natural History of New York.

A $30,000 CONTRIBUTION FOR COOPERATIVE RESEARCH

A very striking example of how cooperative research may work out in practise is shown by the recent contribution of $30,000 made by the General Electric Co., to extend into the field of Nickel Steels, the investigations of the Committee on "Fatigue Phenomena of Metals", of the Division of Engineering of the National Research Council. This work was originally planned to cover carbon steels only, and was heretofore supported by Engineering Foundation, which appropriated $30,000 for two years' work, and by the University of Illinois which contributes the equivalent of about $12,000 in the services of Professor Moore, and in space, heat, light, etc.

Although fatigue failures of metal parts subjected to rapidly alternating stresses have been recognized for many years, the

recent era of high speeds has yielded cases of great number and importance; in connection with steam turbine shafts and rotors, airplane engines crankshafts, the hulls of steel ships, axles and shafts in railway cars, motor cars and trucks, and other machine parts. Such metal parts occasionally fail under ordinary service conditions without showing any general distortion or other symptom even when the material is known to be highly ductile. These failures are found only in parts subjected to alternations of stress repeated in some cases millions of times, and therefore are attributed to fatigue of the metal.

Recognizing the value of the results of these investigations to the industries of the country, Engineering Foundation Board about a year ago made a grant of $15,000 a year for a period of two years for the investigation of fatigue phenomena in carbon steels, under a committee of the Division of Engineering of the National Research Council. Articles of agreement were drawn up between the National Research Council, Engineering Foundation and the University of Illinois, whereby the experimental work was to be done at the University of Illinois under the direct supervision of Professor H. F. Moore, Chairman of the Committee. In addition to the services of Prof. Moore, the University furnishes the necessary space and facilities for conducting the work to the best advantage.

Professor J. B. Kommers of the University of Wisconsin, a specialist in this subject, has secured a two years leave of absence and is devoting his full time to the work, together with a staff of assistants. The apparatus is all installed and the work progressing according to schedule.

The General Electric Company has recently signed an agreement with Engineering Foundation, National Research Council and the University of Illinois, whereby it agrees to contribute an additional sum of $30,000 to extend the work to include 3 per cent and 3½ per cent nickel steel. This extension is to be considered part of the original program and no restriction is placed by the General Electric Company on the publication of results.

Although the results of this work on Nickel Steels will be of immediate commercial value to the General Electric Company, it will also be of value to other manufacturers. The attitude of the Company is therefore an unusually broad-minded one. On the other hand great economies will result from the cooperation agreed to. This is easily appreciated when one considers that the facilities, the supervising experts, and much of the apparatus for conducting these tests are already available and that the consulting services of a group of the foremost experts in the country is furnished without cost, the chief additional cost being some additional apparatus and junior assistants.

Moreover the cooperative method with its concentration of talent makes much more likely the discovery of the fundamental laws of fatigue, which will be vastly more valuable than the mere empirical information as to fatigue limits of two varieties of steel.

Thus the broad-gage, far-sighted policy of the General Electric Company demonstrates the commercial feasibility of co-operative research in the fundamentals of engineering, and opens up a large field of usefulness to the National Research Council and Engineering Foundation. It is also an illustration of the large cumulative returns likely to accrue from a wisely placed investment such as that made by the Engineering Foundation Board, which gave the necessary initial impetus to this movement.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

LECTURER ON INDUSTRIAL TOPICS. An educational organization of high standing, which is working with many of the most important industrial companies in training foreman and workmen, requires the services of an experienced factory man who is well equipped to give popular lectures on industrial topics. This man must have a forceful and attractive personality. Z-1494.

INDUSTRIAL ENGINEERING FIRM, having a number of substantial annual retainers for engineering and management of industrial plants wishes to balance its organization by the association of a Sales Engineer, competent to take full charge of advertising and sales of service. Location N. Y. C. Z-1898.

ELECTRICAL OR MECHANICAL ENGINEER, preferably a young man with one or two years field experience and some experience in office work. Location N. Y. C. Z-1893.

ENGINEER INSTRUCTOR, A Graduate Electrical Engineering course, under 30 years, required by well known school in New York City, to teach practical elements of Electricity, Mechanics and Heat, to students in electrical engineering courses, opening beginning September; position permanent; initial salary up to $2,500; future prospects dependent on qualifications on appointee; give full personal, educational and experience data and references; also religious affiliations; send photograph if possible; state salary expected. Location N. Y. City. Z-1888.

ASSISTANT SUPERINTENDENT of lighting and power department. Duties are supervising the operation and maintenance of a steam plant, a gas plant, a hydro-electric plant, and distribution from these plants for a city of 30,000 population. Man who is at present employed in similar work,—gas experience not absolutely necessary,—in smaller city and who would consider this position as a promotion. Location Virginia. Z-1872.

ASSISTANT SUPERVISOR for printing department of a large corporation. Must have experience in printing technique, and be familiar with office management as work will consist largely of forms, papers, etc., for modern office systems. Age 29 to 40. Location New York State. Z-1875.

INSTRUCTOR, Electrical Graduate Engineer, who has had some teaching and some practical experience. Location New York. Z-1853.

HEATING & VENTILATING, PLUMBING AND ELECTRICAL DESIGNERS with some field experience on installations, in office, factory, and general industrial buildings. High grade men, good personality, three years contract. Foreign service with large American interests. Z-1838.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING to direct laboratories and teach direct current theory. Early promotion for right man. Thorough training and some experience required. Applicants should mail complete information with letters from references and wire for details. Location Washington. Z-1829.

POWER HOUSE ENGINEER. Plant consists of 2—2500 Kilowatt Curtis Turbines with Stirling boilers and mechanical stokers. The position would be to look after the boiler room primarily and all mechanical features of the power house. Location China. Z-1831.

ELECTRICAL ENGINEER, one who is capable of laying out a complete railway system about 18 miles in length and assuming entire charge. Location Chile. Z-1833.

ASSISTANT PROFESSOR and an instructor in electrical engineering work commencing last week in September. Applicants please state qualifications, the minimum salary they would consider and give references. Location Washington. Z-1822.

ASSISTANT TO EXECUTIVE in large commercial laboratory specializing in the testing of incandescent lamps. Technical training necessary. Age 25 to 30. Must be capable of planning and supervising tests and guiding routine thereof. Location New York. Z-1809.

TESTER, Physical tester familiar with Brimel Scleroscope work and having experience in the general physical testing of materials. Man having chemical and metallurgical training preferred. State age, experience, and salary expected. Location Pennsylvania. Z-1794.

DESIGNER, mechanical designer with practical experience on electric switching apparatus. Permanent work for the right man. State age, experience education and salary expected. Location Pennsylvania. Z-1795.

ELECTRICAL SWITCHBOARD AND PANELBOARD DRAFTSMAN to detail panels and switchboards for industrial lighting and power work. State age, experience, references, and salary desired. Location New York City. Z-1783.

MECHANICAL ELECTRICAL ENGINEER. About ten years experience for large phosphate mining property. Desire a man to supervise the installation of new work and to check up our present installation. Applicants furnish references and a record of past experience. Location Florida. Z-1788.

TECHNICAL GRADUATE, with some teaching experience and some experience in the designing and testing of electrical machinery, to take charge of a dynamo laboratory, together with some classroom work, in a day and evening technical school in New York. Write particulars, regarding age, education and experience. Location New York. Z-1789.

PRODUCTION ENGINEER. For company manufacturing full line of Gas, Coal and Electric Ranges. Preferably with technical training although not absolutely essential. Must be capable of completely organizing production system and possess full understanding of the necessities of the position. Excellent opportunity for right man. Location Ohio. Outline past experience and state salary expected to start with in first letter. Z-1792.

GENERAL MANAGER for established Steel Stamping and Rolling concern in New England. Extensive sales experience and superior executive ability necessary. State business and personal qualifications, education, experience, etc. Location Mass. Z-1793.

GRADUATES who desire to connect with a large Manufacturer of Miscellaneous Electrical Household appliances located in Chicago, Ill. Need four men from 1919 or 1920 graduate class who are ready to spend one or two years learning the details of engineering, Sales, Production or Manufacturing Department. Location Illinois. Z-1776.

ELECTRICAL DRAFTSMAN who is able to lay out wiring for industrial lighting and power work. One having had experience with some electrical contractors or engineers desired. State age, experience, references and salary desired. Location N. Y. City. Z-1782.

ASSISTANT PROFESSOR for department of Electrical Engineering in college in south. Apply by letter only giving details of experience, etc. Z-1762.

INSTRUCTOR in Electrical Engineering needed by college in South. Send full details of training and experience with first letter. Z-1763.

LABORATORY MAN for commercial and experimental testing of dry cells. Age 21 to 30. Technical graduate preferred. Must be able to supervise assistant. Location Jersey City, N. J. Z-1770.

ELECTRICAL ENGINEER for large electrical testing Laboratory. Work leads to research and development and covers a very wide range of industrial and measuring apparatus. Application by letter only. Location New England. Z-1771.

ASSOCIATE PROFESSOR for department of Electrical Engineering in college in South. Apply by letter only giving details of experience, etc. Z-1751.

INSTRUCTOR, who can take entire charge and responsibility for the courses, both as to planning and presentation, electrical engineering, laboratory work for juniors and seniors, and a course in machines for seniors. Location Texas. Z-1758.

INSTRUCTOR IN ELECTRICAL ENGINEERING. Cornell University needs several additional instructors in Electrical Engineer, duties beginning September 15th. Candidate must be an engineering school graduate. Opportunity offered to pursue post graduate work. Apply directly to Department of Electrical Engineering, Ithaca, New York, stating age, education and experience and enclose small photograph if available. Z-1727.

INSTRUCTOR to fill responsible position in a high grade technical institution in Mass. Subjects, electricity, physics and mathematics. Practical knowledge of electrical installations in textile plants desirable but not necessary. State fully experience, age, salary expected, etc. in first letter. Location Mass. Z-1711.

INSTRUCTORS for large university, in Architecture, Civil Engineering, Electrical Engineering, Mechanical Engineering, Theoretical and Applied Mechanics, Physics and Railway Mechanical Engineering. Location Middle West. Z-1701.

INSTRUCTOR to teach either or both electrical and mechanical engineering. Prefer young man with some practical experience or man who desires to come to the Pacific Coast for personal reasons. Location California. Z-1599.

INSTRUCTORS AND ASSISTANT PROFESSOR for Mechanical Engineer Department of large University. Location Illinois. Z-1603.

ASSISTANT PROFESSOR capable of handling A- C. & D- C. theory and laboratory. No other work in E. E. required next year, but will be expected temporarily to assist the Department of Physics. Location North Carolina. Z-1498.

ENGINEERS for research and development work on radio apparatus. Applicants should have an electrical engineering degree or its full equivalent in training and experience and must have had substantial experience in radio engineering. Apply by letter only to Engineering Manager, International Radio Telegraph Company, 326 Bway, New York City, stating age, education, radio experience, references, and salary desired. Z-1504.

INSTRUCTOR IN ELECTRICAL ENGINEERING for 11 months work commencing September 1st. Candidates should be graduates with an Electrical Engineering degree and should have had some experience either in practical work or in teaching. Location Ohio. Z-1359.

LABORATORY INSTRUCTOR in Electrical Engineering at a midwestern State College. Position open September 1st, 1920. Z-1292.

INSTRUCTOR IN ELECTRICAL ENGINEERING. Duties beginning September 1st, in New England Engineering College, mainly instruction in electrical engineering Laboratory. Graduate of one or two years engineering experience desired. Z-1284.

INSTRUCTORS. An examination will be held in Sampson Hall, U. S. Naval Academy, Annapolis, Maryland for selection of two instructors in Department of Electrical Engineering and Physics. Examination will be competitive and candidates found qualified will be eligible in the order of merit as determined by the Board of Examiners for appointment to fill vacancies in this department. Should more qualify than there are vacancies for at present, their names will be placed on a reserve list for later appointment to subsequent vacancies if they so desire. Appointments will be made immediately to those qualifying for the above vacancies and will thereafter be renewed annually on July 1, provided performance of duties has been satisfactory. Salary on original appointment is $2000 and an increase of $100 is given on each reappointment. Instructors are eligible for appointment as Assistant Professors, salary $2400, after 2 years, and as Associate Professors, salary $3000 after 5 years. Appointment to Professor after 10 years, salary $3600 with 10% increase every 5 years. Candidates must be American citizens. The age limits are 25 to 35 years though these may be waived in special cases. Candidates must have completed satisfactory professional courses in recognized colleges or universities. In grading the candidates, due weight will be given to past experience, letters of recommendation, etc. The examination will be written and will cover the following subjects: (1) first year college chemistry; (2) elementary and advanced physics, (more particularly those subjects pertaining to Electrical Engineering); (3) Laboratory work to correspond to (1) and (2); (4) Principles of Direct and Alternating-Current Electricity including, storage batteries, direct and alternating-current machinery elementary, telephony and radio telegraphy. Z-1064.

ASSISTANT TO CHIEF ENGINEER, a man with a good engineering education and not less than ten years experience in the design and operating of large steam power plants. Preferably one who has had training in large metal working establishments and is familiar with furnaces, gas producers

and metal working machinery and practise. Location Pa. Z-1934.

OPERATING SUPERINTENDENT, experienced in handling B. & W. Boilers, Curtis horizontal turbines, motor-generator sets, 120 ton electric locomotives operating on 2400 volts D. C. Only experienced men need apply, best of references required. State full particulars in first letter as to age, experience and when available. Location Chile, South America. Z-1940.

MEN AVAILABLE

ELECTRICAL ENGINEER, 25, graduate 1918. Naval Engineering officer during war. One year hydroelectric power plant appraisal. At present assisting General Superintendent of western power company. Desire change offering future possibilities either in Engineering or Commercial field. E-2296.

DRAFTSMAN ENGINEER, experienced on oil well machinery, manufacture of 6 in. shells and equipment for manufacturing same; general construction in large asphalt refinery; graduate E. E. 1915. Accustomed to team work. Want to connect with Company affording excellent opportunity for service, growth, and responsibility. E-2297.

ELECTRICAL ENGINEER, 25, graduate evening session—21. Six years business and electrical experience in construction field, desires position as Assistant to Industrial, Sales or Construction Engineer. Location until June 21st. Must be New York City. E-2298.

EXECUTIVE ENGINEER, Columbia Graduate, E. E., experienced in plant construction; factory management, financing; as general manager; and estimating. American. Age 45, Christian. Salary $6000. If desired could invest $6000 and enlist excellent banking connections. E-2299.

POWER ENGINEER, good executive, 14 years experience operation, maintenance and supervision of power plants, steam and hydraulic. Desire connection with public utility or will undertake the organization or reorganization of power department for industrial concern. Location Middle Atlantic or Southern States. Available one month after closing agreement. E-2300.

GRADUATE ELECTRICAL ENGINEER, 27, married, desires position as Assistant Engineer in General municipal or Public Utilities work where some experience and good judgment are required. In charge of electrical construction and maintenance for two years. Handling 35 men. Can furnish references or recommendations. Salary depends on location. E-2301.

GRADUATE E. E. experienced designer of alternating current motors and generators; also fractional horse power direct and alternating current motors. Desires position with an aggressive manufacturing concern. Location anywhere. Available immediately. Salary $2600. E-2302.

SALES ENGINEER desires connection vicinity Chicago. Technical college graduate. General Electric Test experience and commercial training. Salary $2500. Available soon. E-2303.

ELECTRICAL MECHANICAL ENGINEER, technical graduate, 17 years experience mostly in responsible charge of design, construction and operation of industrial power systems. Have successfully handled several large projects requiring engineering skill of the highest order. Available soon. E-2304.

ELECTRICAL ENGINEER, 31, married. Broad experience; electrical contracting, transformer and motor testing, transformer and motor designing, sales engineering and quotation work with manufacturing companies. Desire location in the middle west or Pacific Coast. Asst. or chief engineer of industrial concern preferred. Salary $3600. E-2305.

YOUNG MAN, 25, desires position with engineering or construction firm where opportunity for an executive position in future is good. Technically trained along electrical lines. Four years maintenance experience with large public utility and 3 years business experience. Best references. Available on short notice. E-2306.

ENGINEER, Supervising and Operating. Seeks position of responsibility in charge of electrical and mechanical industrial power equipment. M. I. T. Graduate, 10 years experience, in the design, installation, testing, operation and maintenance of industrial apparatus. Married. Location desired New York City or vicinity. Available on short notice. E-2307.

CONSTRUCTION ENGINEER desires to exchange services for course of instruction in technical school or University. 15 years experience electrical construction, and operation machine shop and foundry practise. Semi-technical education. E-2308.

GRADUATE ELECTRICAL ENGINEER, 1915, knowledge of electrical apparatus of small and medium size and manufacture of same. Experience in handling high voltages, writing specifications and in selecting apparatus to fill customers' specifications. Married. Desire position in Engineering Sales or executive position with small electrical manufacturing concern. E-2309.

ELECTRICAL ENGINEER graduate desires position with manufacturing or construction company in middle west. Two years experience construction work and drafting, one year electrical officer on submarine. Single, 27, available about Sept. 15. Minimum salary $2500. E-2310.

RAILROAD TELEPHONE INSPECTOR, young with 5 years practical experience in various lines of railroad telephony. Good technical education. Desires change offering position with broader opportunities. E-2311.

ELECTRICAL ENGINEER, 25, familiar with preliminary surveys, operation and maintenance work desires a position with hydroelectric concern in the Northwest. Salary $175. E-2312.

ELECTRICAL ENGINEER, desires business, engineering or sales position with a growing concern. Fifteen years experience which has included design, construction and operation of electric railway, power-house and substation work; also correspondence and sales experience and motor application for industrial plants. Salary $300.00 per month. E-2313.

ELECTRICAL ENGINEER, 24, single, seeks larger field. Degree from American College. One year construction experience. One year efficiency and experimental, eighteen months technical salesman on heavy electrical machinery in Great Britain. Located at present in London. Conversant with foreign business methods. Knowledge of French and Spanish. Present salary $3500. E-2314.

ASSISTANT TO CONSULTING ENGINEER, of large industrial organization. 30 years experience including 4 as millwright and locomotive builder; 5 as chief draftsman; 5 estimating and sales manager; 5 chemical engineering research. Also important consulting work, America, England and Australia. Lecturer at several leading Universities and Technical Institutes. Editor proceedings Mining Engineering Society and good writer technical articles and advertisements. Special knowledge of design and working electric furnaces. Would consider position as Professor, Editor or Secretary of Technical Society. E-2315.

GENERAL ENGINEERING WORK, wanted by member; now employed as investigating engineer by high grade Investment Securities House in New York. He desires a change that will give him active (partial or entire) outside or road work in which he may utilize twelve years experience in sub and central station design. Installation and operation, with the country's largest central station company, and four years on hydro and substation design and hydraulic investigations and tests with a well known engineering company. E-2316.

ELECTRICAL SUPT. of operation and maintenance. Technical graduate. 18 years practical experience on all kinds of operating and load dispatching. Chief Electrician of central stations, both lighting and railway and Superintendent of lighting, railway and power substations indoor and outdoor type. Desires position as superintendent of operation and maintenance, with Utility Company or large Industrial Concern. Age 34, married, references. At present employed have good reasons for change. E-2317.

ELECTRICAL ENGINEER, technical graduate, 5 years experience, powerhouse, substation and electric railway equipment and maintenance. Pump installations. Considerable experience on cable specifications and inspections. Initial salary $200 per month. E-2318.

YOUNG MAN, 23, B. S. in E. E., 1920. Fluent Spanish and French. Desires position in U. S., foreign country with a successful firm. Available January 1921. E-2319.

OPERATING ENGINEER, technically educated, ten years General Electric Test, fifteen years steam and hydro-electric generation, high tension transmission and distribution, proved executive ability, at present holding position as Superintendent of Power large hydroelectric company, desires change. Correspondence and interview solicited. Age 40, married, present salary $5000.00. Address E-2320.

ENGINEER, Technical graduate, 2 years G. E. Test, 2 years Assistant Chief in 50,000 Kw. station, 1 year Superintendent of betterment work in 3000 Kw. station and 55 ton ice plant, desires permanent connection with chance for advancement. Salary desired $3600. E-2321.

ENGINEER AND MANAGER. Technical and practical. Two years as Manager of electric and gas properties. Two

years traveling operating and supervising engineer for large holding company. Ten years engineering and operating with The New York Edison Co. Prefer location in East. Available on 45 days notice. Salary $6000. per annum. E-2322.

MECHANICAL OR PLANT ENGINEER. Technical, graduate excellent executive; successful in handling all classes of men; diplomatic and tactful. 18 years experience in electrical and mechanical including; installation and maintenance; industrial plant, power, heating and lighting layout; organization and production engineering, and purchasing. E-2323.

YOUG MAN, age 25, married; partial technical training. Five years electrical experience actual construction, engineering, and drafting, designing of power plants and substations, switchboards and general electrical installations. Desires position with prospects for advancement. Location Philadelphia or near by. Available immediately. E-2324.

YOUNG ELECTRICAL ENGINEER. Cornell '18, desires connection with consulting engineer or small growing technical concern. Practical experience, personality, vigor, ability and judgment. E-2325.

ENGINEER SUPERVISING or operating chief; position of responsibility in charge of power plants or plant and mechanical and electrical industrial equipment especially where proportionately large amount of steam and power is used in manufacturing; 20 years experience. Married. Location immaterial. Salary commensurate with position. Immediately available. E-2231.

ELECTRICAL ENGINEER. B. S. in E. E., 12 years experience in electric meters and instruments; distribution control, signal and telegraph apparatus; insulating material. Desires position as assistant to production engineer or as Manufacturers representative. American, 31, married. E-2327.

ELECTRICAL ENGINEER. 30, married, technical graduate Westinghouse Test Course. Employed as electrical engineer and superintendent of Electrical Department, 400 men, 1600 motors up to 5750 hp., 125 cranes, turbo-generators totalling 44,000 Kw. Desires position as Electrical Engineer with large industrial concern. Available 30 days notice. Salary expected, $6000.

PRACTICAL MECHANICAL and Electrical Engineer desires position as assistant to supervising engineer on electric power station or electric railway construction work. Have had 6 years practical experience in mechanical and electrical construction and maintenance work; 4½ years supervising inspecting and testing of machinery and electrical equipment for foreign governments; 12 months as staff engineer in an industrial plant, handling estimates, specifications, machinery installation and maintenance supervision. Graduate marine and stationary engineer; with I. C. S. Electrical Engineering Diploma. Age 28, married, location immaterial. Salary $2400 to start. E-2329.

ELECTRICAL CONSTRUCTION or operation preferred, research or design instruction and drafting acceptable in order named. Two years Westinghouse Shop and test work, six months Goodrich design and drafting work. Technical graduate Johns Hopkins. E-2330.

TECHNICAL GRADUATE, four years laboratory experience in magnetics, thoroughly versed in modern methods of testing electrical steels and materials, desires position with manufacturing concern in need of man with the above training and experience. Salary commensurate with duties and location. Available on reasonable notice to present employer, married, age 20. E-2331.

MECHANICAL AND ELECTRICAL ENGINEER, Technical and Executive, 14 years practical experience in electrical and mechanical construction and sales, including power plants both central station and industrial. Married. Services available October 1st. Minimum salary $5000 per annum. E-2332.

ELECTRICAL ENGINEER, technical graduate, seven years experience desires opportunity for broader business training as assistant to chief executive of manufacturing plant. Generally familiar with plant management, apparatus design, production, cost finding and accounting. At present employed as executive in engineering department of large corporation. E-2333.

ENGINEER, Age 44, 25 years experience in design construction and operation of steam, electrical systems and industrial layouts, now employed Chicago; desires position vicinity Los Angeles, Cal. E-2334.

MECHANICAL SUPERINTENDENT, for textile mills. Technical graduate, thirty nine, member. Wide experience in mill work including the design and installation of electric drives. Also thorough training in steam engineering using both coal and fuel oil. Good executive. Best references. E-2335.

ASSISTANT ENGINEER, 25, married, technical education 5 years experience in contracting, testing and construction. Last two years with electrical traction company on substation construction work, comprising general supervision of switchboard construction. E-2336.

ELECTRICAL ENGINEER, of broad experience, available for employment in America or abroad. College graduate. Sixteen years with leading manufacturer, testing hydro-electric construction, America and abroad, design, development, investigation, export sales, speaks French and is familiar with conditions in India. E-2337.

GRADUATE ELECTRICAL ENGINEER, B. S. Design work-power stations and transmission five years. Industrial light and power three years. Steam turbines one year. Electrical manufacturing office three years. Electrical construction work one year. Test three years, factory and Edison Co. Business three years. Executive experience. Now employed. Either commercial or technical position. E-2338.

ELECTRICAL AND MECHANICAL ENGINEER, graduate, 6 years university training and 8 years practical experience. Electrical design, construction and maintenance. Mechanical installation and maintenance. Experience in handling personnel. Administrative duties. Business course 30% complete. E-2339.

ELECTRICAL ENGINEER. Technical graduate. Age 29. Five years broad experience design and purchasing. Capable, energetic. Easily adapted to new situation. Wants permanent position. Available 30 days notice. Salary $2700. E-2342.

EXECUTIVE, technical graduate in Electrical Engineering. Public Utility and Metal Manufacturing experience. Available on thirty days notice for allied position or with efficiency or sales organization. Minimum basis $5000, prefer lesser fixed salary with share or bonus proportionate to results. E-2340.

ELECTRICAL ENGINEER, with 14 years exceptionally broad experience in the electrical utility and hydroelectrical field covering both design, construction, testing and operation of modern power systems (incl. electrical furnaces). Specialty. Investigation and relief of difficult operating problems. At present in charge of research dept. of Power Company: Age 37, Married. E-2341.

ADDRESSES WANTED

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—W. Ammen, 133 Franklin Ave., Mt. Vernon, N. Y.
2.—L. J. Clements, 469 Magnolia, Portland, Ore.
3.—Oliver H. Horner, c/o Black & Veatch, 507 Interstate Bldg., Kansas City, Mo.
4.—Wilfred Langille, Marion Sta. Public Service Elec. Co., Jersey City, N. J.
5.—Harry Symes, Lyne Mfg. Co., Orange, Va.
6.—David R. Thomas, Otis & Co., Cleveland, Ohio.

PERSONAL

L. B. RITCHIE has been appointed general eastern sales manager for the Burke Electric Company, with headquarters at 30 Church Street, New York City, where he has for some time been sales representative for the New York territory.

GEORGE M. BASFORD, president of the Locomotive Feed Water Heater Company, New York, has been appointed a Trustee of United Engineering Society to fill the vacancy caused by the death of E. Gibbon Spilsbury. The term will expire at the annual meeting in January, 1923. Mr. Basford was formerly a member of the Council of the Mechanical Engineers.

C. D. YOUNG, general supervisor of stores, Pennsylvania System, Broad Street Station, Philadelphia, and vice-president of the American Society for Testing Materials, has

been appointed by the American Society for Testing Materials as its representative on Engineering Council to succeed Mr. Albert Ladd Colby.

L. L. MYERS has been appointed general western sales manager for the Burke Electric Company. Mr. Myers' headquarters will continue to be in the Illuminating Building, Cleveland, Ohio, where he has been the Burke Electric Company's sales representative for the Cleveland territory for several years.

G. SANFORD DAVIS is leaving the employ of the Canadian General Electric Co., Ltd., where he has been for the past fifteen years, in the Engineering Department, and lately as District Engineer in the Montreal office. He will enter the employ of J. M. Robertson, Ltd., Consulting Engineers, in the Cornstine Building, Montreal.

H. J. VAN DER BIJL, Research Physicist with the Western Electric Company, New York, will soon leave the United States. He has accepted the call of his birthplace and will proceed immediately to his home at Pretoria, British South Africa, where he has been appointed Scientific and Technical Advisor to the Bureau of Mines and Industries of the Union of South Africa. His duties will consist for the main part in establishing a bureau of standards for the authorities of the Dark Continent. Dr. Van der Bijl comes from an old family of Boers. During the time that Lord Roberts was operating about Pretoria, the father of the well-known scientist was mayor of the doomed city. A few years later Dr. Van der Bijl finished his studies at Victoria College, British South Africa, thereafter entering the University of Leipsic where he gained his doctorate. He came to the United States in 1912, joining the engineering department of the Western Electric Company, and for the last seven years he has been a prominent member of the personnel of its research laboratories at West Street. He was instrumental in devising several of the improvements in telephone and telegraph instruments which the Western Electric Company has brought forth during the last few years. Dr. Van der Bijl became a Member of the A. I. E. E. in 1917.

OBITUARY

EDWARD MARTIN SHEPARD, JR., electrical engineer, of Detroit, Michigan, died suddenly of pneumonia in that city Mar. 24th, 1920. He was born in Springfield, Missouri, Aug. 27th, 1889. He was graduated from Drury College in 1910, and went directly to Cornell University, where he was graduated in 1913 with the degree of electrical engineer. In the fall of that year he became connected with the Wagner Electrical Company, of St. Louis, and was soon sent to act as the engineer in their branch in Detroit. He resigned from this work to become a partner in the firm of Little & Shepard, Electrical and Mechanical Engineers, in Detroit. Immediately upon the declaration of war, he enlisted and received his commission as First Lieutenant at Fort Sheridan the summer of 1917. From Camp Humphries, Va., he was sent over seas Sept. 19, 1918 in command of B Company of a service battalion of the 544th Engineers, and was commissioned Captain May 1, 1919. In the battle of the Argonne his company was in charge of keeping open lines of transportation. After the armistice, his company did much work in road construction in that region, and later in the neighborhood of Brest. Captain Shepard was honorably discharged from service at Camp Grant, Illinois, Aug. 1, 1919. He returned to Detroit and immediately entered upon a responsible connection with the engineering department of the Detroit-Edison Company, which position he held at the time of his death. He came of good old New England stock, the last of a long line of Mayflower descendants, being 10th in descent from Governor Wm. Bradford, and a most promising career was cut short by his death.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (JULY 1—31, 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

APPLIED AERODYNAMICS.

By G. P. Thomson. N. Y., The Norman W. Henley Publishing Co. 292 pp., illus., charts, diagrams, plates, 10 x 7 in., cloth, $12.50.

CONTENTS: Part I. Performance: General Outline; Physical Theory; Experimental Methods; Struts and Wires; Wing Structure; Bodies, Fuselages, etc.; Landing Gears and Miscellaneous Resistances; Airscrews; Large Aeroplane; Prediction of Performance.

Part II. Stability and Control: Centres of Pressure and Moments; Tail Planes and Downwash; Mathematical Discussion of Stability; Longitudinal Stability; Lateral Stability; Controllability.

This book is the work of a former officer in the Royal Air Force, who, during the War, was in touch with both the demands from the Front and the attempts made to fulfil those demands from home sources. The results presented are drawn from data accumulated during the War, some of which has been or will be published in the Reports of the Advisory Committee for Aeronautics, and the author has also had free access to the staff and records of the Aircraft Manufacturing Company. The work is concerned only indirectly with the mechanical side of aircraft design, but it specializes upon aerodynamics as a branch of engineering, though an account is also given of such progress as has been made on this side of physics from an engineer's point of view.

A number of suggestions for further inquiry and research are made, such as the problems relating to the interaction of aeroplane fuselages, nacelles and the airscrews attached to them.

The importance of full-scale work is emphasized, and the problem of stability is dealt with at length. The question of how heavily the wings of an aeroplane should be loaded is discussed and the subject of abnormally large aeroplanes is also taken up. The information given was up-to-date at the time of writing and pains have been taken to point out the cases in which there was any considerable probability of error.

THE COAL CATALOG, COMBINED WITH COAL FIELD DIRECTORY FOR THE YEAR 1920.

Containing Explanatory Articles on Rank, Usage, Analysis, Geology, Storage and Preparation of Coals. Compiled and published annually by Keystone Consolidated Publishing Company, Pittsburgh. 1133 pp., illus., maps, tables, 12 x 9 in., cloth, $10.

The second edition of the Coal Catalog, in addition to describing and listing the coal mines of the United States, with the output and operating companies, has added much new data such as the fusion points of ash from the various coals, the specific gravities and weights of coals and the so-called "fuel ratios." A list of national and local associations is included as well as the wholesale dealers in the larger towns and cities. A Directory section follows each state.

A METALLOGRAPHIC STUDY ON TUNGSTEN STEELS.

By Axel Hultgren. N. Y., John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd. 1920. 95 pp., illus., 43 plates, tables, 9 x 6 in., cloth, $3.00.

As the question of tungsten steels has been studied by several investigators whose views have not always agreed, it is the purpose of this work to bring about a clearer understanding by presenting certain new facts and problems and by critically examining previous results and opinions.

The subject is divided into two sections: (1) The transformations of tungsten steel during different heat treatments and the structures thereby formed; (2) Carbides in tungsten steels. Each section contains a review of the results and opinions of previous investigators and the author's own results and conclusions, based on his metallographic investigations at the Institute of Technology of Charlottenburg, the Royal Institute for Testing Materials, Stockholm, and in the Laboratory of the S K F Ball Bearing Co., Gothenburg, Sweden.

The paper was written in Swedish in 1918. In its present form it includes a translation of the Swedish paper as well as an appendix containing a critical review of the investigations on tungsten steels of Honda and Murakami.

POPULAR OIL GEOLOGY.

By Victor Ziegler. Second edition. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 171 pp., illus., chart, maps, tables, 7 x 5 in., flexible cloth, $3.00.

CONTENTS: The Rise and Development of the Petroleum Industry.—The Composition and Properties of Oil and Gas.—The Origin of Oil and Gas.—Rocks and their Properties.—Stratigraphic Geology.—The Arrangements and Structures of Rocks.—The Reservoirs of Oil and Gas.—The Laws of Migration and Accumulation of Oil and Gas.—Maps and their Uses.—Oil Structures and Oil Fields.—Popular Fallacies in Oil Geology.—Prospecting and Developing Oil Lands.—Oil Shales and their Utilization.—Oil Investments.

The second edition of this work on oil geology has been partially rewritten and new material along the more theoretical lines of geology has been added. The principles important in the examination of prospective oil land have been emphasized and the work of the oil geologist described in some detail. The work is intended to make intelligible to the laymen the fundamental principles of oil geology and is written in as clear and simple language as possible.

PRACTICAL CHEMISTRY.

Fundamental Facts and Applications to Modern Life. By N. Henry Black and James Bryant Conant. N. Y., Macmillan Co., 1920. 474 pp., illus., plates, 8 x 5 in., cloth, $2.00.

It is the purpose of this book to present the fundamental facts of chemistry and to show by the applications of those facts to experiences of everyday life that the subject is real and practical. The economic significance of chemistry and the allied industries has been stressed and the chemistry of growing things has also been considered. Only such topics have been included as young people can grasp and find useful. The book is adapted for class use as a textbook.

SPOT AND ARC WELDING.

By H. A. Hornor. Phila. and Lond., J. B. Lippincott Co., copyright 1920. 296 pp., illus., charts, diag., 8 x 5 in., cloth.

Although electric welding has long been used in repair work, there is still considerable hesitancy in applying it in new construction work. This volume is intended to overcome this hesitancy by presenting the results of work already done. The data of tests made in the spot welding of heavy steel slates by the Emergency Fleet Corporation is given in full and the underlying question of arc-welding processes is dealt with at length.

The appendix contains lessons in electric welding and the regulations for the application of electric arc welding to ship construction issued by Lloyd's Register of Shipping.

STORAGE BATTERIES.

A Practical Presentation of the Principles of Action, Construction, and Maintenance of Lead and Non-lead Batteries and Their Principal Commercial Applications. By Morton Arendt. Chic., American Technical Society, 1920. 136 pp., illus., plate, tables, 7 x 6 in., flexible cloth.

CONTENTS: Theory and Principles.—Lead Batteries.—Non-lead Batteries.—Testing Storage Batteries.—Regulation of Generator in Charging Storage Batteries.—Commercial Applications.

Important changes have taken place with the last ten years in the construction of the storage battery, and the principles of the design and manufacture of this "savings bank" of the electrical industry have been studied with the view of making it even more efficient. The importance of proper charging methods, testing, locating and remedying troubles are treated in detail in this volume, which also covers the methods of use by the large generating stations, in the telephone and telegraph industries and in electric vehicles. The work is adapted for home study by beginners as well as for experts.

THEORIE DES HELICES PROPULSIVES, MARINES ET AERIENNES.

Et des Abions en Vol Rectiligne. By A. Rateau. Paris, Gauthier-Villars et Cie, 1920. 159 pp., diagrams, tables, 10 x 7 in., paper. (Gift of author.)

The first part of this work deals with the theory of screw propellers, both marine and aerial, and is an extension of the author's previously expressed hypothesis. A large number of formulas are worked out and compared with the results derived from experiments.

The second part, which takes up the theory of planes in rectilinear flight, is based on four papers presented to the Académie des Sciences in 1919, with some corrections and additions, particularly the formulas for the angle of incidence and speed of ascension, the effect of the angle at which the axis of the propeller is inclined, the characteristic curves of planes and the changing of speed rotation indicated by their discontinuity, etc.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Cincinnati.—July 27, 1920, The Engineers Club of Cincinnati. Organization meeting and election of officers as follows: Chairman, J. D. Lyon; Secretary-Treasurer, Leo Schirtzinger; Executive Committee, Prof. A. M. Wilson, C. W. DeForest, and Wm. S. Culver. Attendance 20.

Ithaca.—May 28, 1920, Technology Club, Syracuse, N. Y. Subject: "Alternating-Current Railways" Speaker: Mr. R. E. Hellmund, of the Westinghouse Elec. & Mfg. Co. Preceding the meeting a get-together dinner was held in the Onandaga Hotel in honor of the speaker of the evening. Attendance 100.

Kansas City.—June 25, 1920, University Club Rooms. Subject: "The Structure of the Automatic Telephone Exchange." Speaker: Mr. Artnur B. Smith, of the Automatic Electric Company, Chicago. Attendance 28.

Vancouver.—June 16, 1920, Board of Trade Bldg. Reorganization meeting. Two visiting members from the Toronto Section outlined the recent activities of that Section. Attendance 15.

June 22, 1920. Annual meeting. Election of officers as follows: Chairman, Frank Sawford; Secretary, T. H. Crosby; Executive Committee, Messrs. J. R. Read, R. F. Hayward and F. W. McNeill. Attendance 26.

PAST BRANCH MEETING

Drexel Institute.—June 16, 1920. Election of officers as follows: Chairman, George Davis; Secretary, Franklin Peterson; Treasurer, Holmer S. Kepner. Attendance 16.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED AUGUST 12, 1920

Adams, Charles W., Supt. & Engineer, Brush Dept., United States Graphite Co., Saginaw, Mich.

Aldrete, Antonio, Electrical Engineer, Cia Hidroelectrica e Irrigadora del Chapala S. A., 11d del Juarez No. 682, Guadalajara, Mexico.

Andres, Paul G., Asst. Professor of Electrical Engineering, Michigan Agricultural College, E. Lansing, Mich.

Appleman, Glen, Electrical Engineer, The Lehigh Valley Lt. & Pr. Co., 8th & Hamilton Sts., Allentown, Pa.

Baerer, Eugene A., Test Engineer, The Lehigh Valley Light & Power Co., Hauto; res., 3 North Lehigh St., Tamaqua, Pa.

Bankus, John, Electrical Engineer, Portland Railway, Light & Power Co., 507 Electric Bldg., Portland, Ore.

Beckel, George J., Meter Man Public Service Co.; res. 1617 Oak St., Chicago Heights, Ill.

Benington, William F., Electrical Designer, Semet-Solvay Co., Syracuse, N. Y.

Bente, Saunders H., Division Inspector, Public Service Company of Northern Illinois, Kankakee, Ill.

Betts, Andrew G., Meter Supt., Puget Sound Power & Light Co., 1306 A St., Tacoma, Wash.

Bickel, Joseph W., Electric Meter Foreman, Division F. Public Service Company of Northern Illinois, Chicago Heights, Ill.

*Binder, Albert A., Service Engineer, Westinghouse Electric & Mfg. Co.; res., 3854 Westminster Place, St. Louis, Mo.

Blair, Wayne C., Industrial Engineer, Kansas City Power & Light Co., 1500 Grand Ave., Kansas City, Mo.

Boneschi, Arturo, Dealer in Electrical Apparatus, Via Romagnosi No. 1, Milan, Italy.

Boring, Herbert A., Sales Agent, General Electric Co., 609 Colman Bldg., Seattle, Wash.

Boyere, Emery E., Interior Wireman, B. & G. Dept., General Electric Co.; res., 311 Sassafras St., Erie, Pa.

Brainard, Charles D., Meter Engineer, Chicopee Electric Light Dept., Chicopee; res., 133 Springfield St., Springfield, Mass.

Bravo, Ricardo S., Jr., Chief Electrician, Sugarland Industries, Sugarland, Texas.

Brown, Robert Q., Acting Instructor in C. E., University of Washington, 4522 18th Ave., N. E., Seattle, Wash.

Browning, Hardy P., Captain, Signal Corps, United States Army, Fort Sam Houston, Texas.

Bryant, Le Roy C., Manager's Assistant, Chicopee Electric Light Dept.; res., 10 Riverview Terrace, Chicopee, Mass.

Buyers, Charles S., Engineer-in-Charge of Contract Dept., Messrs. Crompton & Co. Ltd., Chelmsford, Eng.

Calvert, Leslie W., Chief Electrician, Weyerhaeuser Timber Co., Everett, Wash.

Campbell, Allan B., Electrical Engineer, Board of Railroad Commissioners, Des Moines, Iowa

Carpenter, James W., Industrial Engineer, Union Electric & Power Co., 12th & Locust Sts., St. Louis, Mo.

Casey, Francis R., Electrical Engineer, Western Electric Co.; res., 6820 S. Marshfield Ave., Chicago, Ill.

Chakow, Sig. J., Asst. Electrical Engineer, Condron Co., 1433 Monadnock Block, Chicago, Ill.

Chamberlain, Leon H., Switchboard Engineer, The Pacific Tel. & Tel. Co., 835 Howard St., San Francisco; res., 922 Santa Barbara Road, Berkeley, Cal.

Cheever, Allston H., Electrical Draftsman, Richard D. Kimball Co., 6 Beacon St., Boston; res., 14 Centre St., Cambridge, Mass.

Coakley, Patrick S., Operator, Electrical Division, The Panama Canal, Gatun, Canal Zone.

Cobb, Frank E., Repairman, Union Electric Light & Power Co.; res., 2630 Ann Ave., St. Louis, Mo.

Cockburn, Donald, In charge of Electrical Construction, Aberthaw Construction Co., Boston; res., 48 Cottage St., Melrose, Mass.

Coffin, Frank C., New England Power Co., 35 Harvard St., Worcester, Mass.

Conrad, Lester L., Laboratoryman, So. California Edison Co., 132 Llewellyn St., Los Angeles, Cal.

Corona, Felix F., Consulting Engineer, Jefe del Laboratorio de Electrotecnia de la Universidad de Chile, Casilla 1816, Santiago, Chile, S. A.

*Corson, Le Roy, Asst. Engineer, New York & Queens Electric Light & Power Co., Long Island City; res., 203 Warburton Ave., Yonkers, N. Y.

Counts, Hilda, Graduate Student, Electrical Engineering, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Cox, George C., Cox & Son, Sylva; res., Cullowhee, N. C.

Crawford, Vernon W., Designing Engineer, General Electric Co., Pittsfield, Mass.

*Darland, Alvin F., Chief Electrician, Todd Dry Dock & Construction Corp.; res., 3640 Thompson Ave., Tacoma, Wash.

David, Edward Ivor, Chief Electrical Engineer, Powell Duffryn Co., Aberdare, South Wales, British Isles.

de Coutouly, Gustave Charles, General Direction of French Services (Statistics), 65 Broadway, New York, N. Y.; res., S. Norwalk, Conn.

Denn, Edward J., In charge Electrical Work, Richard Turner Co.; Consulting Engineer, Acme Engineering Service, Springfield, Mass.

Dunlap, Edward F., Traveling Salesman, Economy Fuse & Mfg. Co., Chicago, Ill.

Eckert, William S., Vice-President, National Conduit & Cable Co., Inc., Hastings-on-Hudson, N. Y.

Edwards, Wrightman, Sales Engineer, National Conduit & Cable Co., Inc., 41 Park Row, New York, N. Y.

Fairfield, Donald H., Chief Electrician, The American Brass Co.; res., 971 Howland Ave., Kenosha, Wis.

Ferraz, Raul de Oliveria, Contracting Engineer, Rua Libero Badaro 67; res., Automovel Club, S. Paulo, Brazil, S. A.

Field, Ernest H., Estimating Engineer, Crompton & Co., Ltd., Chelmsford, Eng.

Fisher, William H., Electrical Draftsman, Goodyear Tire & Rubber Co.; res., 1623 Preston Ave., Akron, Ohio

Fletcher, John A., Asst. Dist. Manager, Canadian General Electric Co., Ltd., Vancouver, B. C.

Frankel, Charles B., Asst. Engineer, Underground Extensions, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

Franklin, George E., In charge of Testing Dept., Chamberlain & Hookham Meter Co., Ltd., 243 College St., Toronto, Ont.

Franklin, Townsend U., Sales Engineer, Morgan Crucible Co., 519 W. 38th St., New York, N. Y.; res., Warsaw, Ind.

Friday, Casper S., Test-man, General Electric Co.; res., 203 Seward Place, Schenectady, N. Y.

Gifford, Clarence C., Electrical Engineer, Los Angeles Shipbuilidng & Drydock Co., San Pedro, Cal.

Glass, Howard G., Asst. Operator, Substation, Pennsylvania Water & Power Co.; res., 3127 Guilford Ave., Baltimore, Md.

Godwin, Jimmie Jean, Utility Clerk, Union Electric & Power Co., 315 N. 12th, St. Louis, Mo.

Govier, Charles E., Associate Professor, Telephone Engineering, Pennsylvania State College, State College, Pa.

Grant, Royal E., Industrial Research Engineer, 790 Pleasant St., Dracut, Mass.

*Green, James L., Engineer, Northern Electric Co., Ltd., Regina, Sask., Canada

Gregory, Philip S., Electrical Engineer, Shawinigan Water & Power Company, Montreal, Que., Can.

GROSS, FRANK W., Master Signal Electrician, Signal Corps, U.S. A., Dept. Signal Office, Ft. Sam Houston, Texas.
HAWKINS, ROY A., Chief Electrician The Moctezuma Copper Co., Pachuca, Hidalgo, Mexico.
HENYAN, GEORGE W., Commercial Engineer, Lighting Dept., General Electric Co., Schenectady, N. Y.
HERROLD, CHARLES D., Street Car Industrial Co., 475 S. 1st St., San Jose, Cal.
HILLS, CHARLES B., Electrical Supt., Bathurst Lumber Co., Bathurst, N. B.
HOBSON, ALBERT, Transmission & Protection Engineer, Southwestern Bell Telephone Co., Dallas, Texas.
HOFERT, FRED A., Foreman, Victor Electric Corp., 236 S. Robey St., Chicago; res., 732 S. Humphrey Ave., Oak Park, Ill.
HOLCOMB, PHILO, JR., Multiplex Telegraph Attendant, Western Union Telegraph Co.; res., 431 Central Ave., Atlanta, Ga.
HOOD, CLIFFORD F., Electrical Engineer, Electrical Cable Works, American Steel & Wire Co.; res., 738 Main St., Worcester, Mass.
HOPKINS, HENRY D., Electrical Draftsman, Commonwealth Edison Co.; res., 6057 Drexel Ave., Chicago, Ill.
HRUBES, JAMES A., Engineer, Chicago Elevated Railroads, 72 W. Adams St., Chicago, Ill.
HUBBERT, WILLIAM, Electrical Foreman, Skinner & Eddy Corp.; res., 1323 13th Ave. South, Seattle, Wash.
HULT, GEORGE A., Electrical Engineer, Sioux Falls Div., Northern States Power Co., Sioux Falls, S. Dakota.
IRLAND, GEORGE A., Electrical Dept., Bethlehem Steel Co., Sparrows Point, Md.
JAHN, EMIL, Section Leader, Electrical Drafting Dept., New York Edison Co., 15th St. & Irving Place, New York, N. Y.; res., Scotch Plains, N. J.
JANSKY, CYRIL M., JR., Instructor in Electrical Engineering, University of Minnesota, Minneapolis, Minn.
JOHNSON, CLARENCE L., Telephone Engineer, The Pacific Tel. & Tel. Co., 626 Sheldon Bldg., San Francisco, Cal.
KAWABATA, ITSUO, Electrical Draftsman, Stone & Webster, 147 Milk St., Boston, Mass.
KEISER, WILLIAM P., Draftsman, Century Electric Co., 1827 Pine St., St. Louis, Mo.
KINDERMAN, WILLIAM C., Chief Electrician, Holt Mfg. Co., 444 S. Aurora St., Stockton, Cal.
KISHIDA, KAZUTARO, Electrical Engineer, Shibakawa & Co., 331 Fourth Ave., New York, N. Y.
KRASNOFF, NATHANIEL, Engineering Duty, U. S. Navy, U. S. Naval Academy, Annapolis, Md.; res., Union, S. C.
KYLE, GEORGE L., Sales Engineer, Arc Welder Dept., U. S. Light & Heat Corp.; res., 312 Ferry Ave., Niagara Falls, N. Y.
LANE, ROBERT S., Asst. Service Engineer, Thomas A. Edison Inc., Orange; res., 416 N. Cortland St., Belleville, N. J.
LANG, WILLIAM I., JR., Electrical Engineer, State Transit Construction Commission, 49 Lafayette St., New York, N. Y.
LINDELL, ARTHUR G., Foreman, Armature Dept., Goodman Mfg. Co.; res., 10346 Wabash Ave., Chicago, Ill.
LUTZ, ROBERT S., Sales Engineer, Allis-Chalmers Mfg. Co., Casilla 2653, Santiago, Chile, S. A.
MACKING, NICHOLAS, Electrician, Ancon Hospital, Ancon, Canal Zone.
MADDUX, FRANK N., Sales Engineer, Mechanical Appliance Co., Milwaukee, Wis.
MALLOY, WILLIAM E., Lieut-Commander, U. S. Navy, Navy Yard, New York, N. Y.
McCAIN, VERNON E., Salesman, Western Electric Co., Tacoma, Wash.
McFARLAND, GEORGE I., Supt., Jordan Steam Station, Utah Power & Light Co., 16 Glendale Ave., Salt Lake City, Utah.
McKEEN, ERNEST E., Electrician, Portland Railway, Light & Power Co.; res., 4635 25th Ave. S. E., Portland, Ore.
McKENZIE, ERNEST F., Student Engineer, Testing Dept., General Electric Co.; res., 1 Union St., Schenectady, N. Y.
McMILLAN, A. M., Storage Battery Salesman, Western Electric Co., 84 Marion St., Seattle, Wash.
MEEKER, ROYAL, Asst. Foreman, General Electric Co.; res., 18 Meadow Lane, Pittsfield, Mass.
MERRILL, ZADOC E., Asst. Engineer, Public Service Commission of Washington, Olympia, Wash.
MEYER, GROVER C., Draughtsman, The United Electric Light & Power Co., 130 E. 15th St., New York, N. Y.
MISSION, GEORGES, Directeur-generale de la Societe les Explootations Electriques, 19 rue Louis-Le-Grand, Paris, France.
MOORE, LORENZ P., Electrical Contractor, 811 Shipley St., Wilmington, Del.
MOSES, MARCUS H., Shop Inspector, Pennsylvania Railroad Co., Meadows Shop, N. J.; res., 600 W. 183rd St., New York, N.Y.
NYE, IRVIN W., Electrical Engineer Nazareth Cement Co., Nazareth, Pa.
O'BRIEN, BRIAN, Graduate Student in Electrical Engineering & Physics, Yale University, 10 Hillhouse Ave., New Haven, Conn.
O'LEARY, JOSEPH T., Electrical Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.; res., 431 Spring St., Elizabeth, N. J.
PARANJAPE, VISHNU K., Foreman in charge of Power House & Armature Shop, The Tata Iron & Steel Co., Ltd., Jamshedpur, India.
PARTOES, ALBERT A., Engineer, Energia Electricia de Cataluna, 1 Calle Gerona, Barcelona, Spain.
PILCHER, BASIL B., Quarterman, Charles Cory & Son, Inc., 207 Market St., Philadelphia, Pa.
PLOETZ, CHARLES M., Instructor, School of Engineering of Milwaukee; res., 483 4th Ave., Milwaukee, Wis.
PRESCOTT, CLIFTON S., Telephone Engineer, Western Electric Co., Hawthorne Station; res., 2342 S. Millard Ave., Chicago, Ill.
PRICE, TYLER G., Junior Engineer, Underground Distribution, Commonwealth Edison Co.; res., 527 Barry Ave., Chicago, Ill.
PRITZKER, ASHER, Managing Director, The National Electric Heating Co. Ltd., 544 Queen St. East, Toronto, Ont., Can.
QUINN, JOHN T., Engineer, Western Electric Co., 463 West St., New York, N. Y.
REICHENSTEIN, HERMANN, Draftsman, Singer Company, Elizabethport; res., 534 Adams Ave., Elizabeth, N. J.
RETTIE, CHARLES, Electrical Engineer, Messrs. Gammel Lairds; res., 75 Upper Hill St., Liverpool, Eng.
RHUDY, JAMES T., Asst. Professor, Electrical Engineering, Virginia Military Institute, Lexington, Va.
RODDEY, MARVIN M., Supt. of Operation, Tennessee Power Co., Cleveland, Tenn.
ROELL, FRANK A., Shop Supt., A. H. Cox & Co., Inc. 307 1st Ave. South, Seattle, Wash.
RUREY, BURDETT F., Chief Electrician, Milwaukee Rolling Mill Co., W. Allis; res., 448 Menlo Blvd., Shorewood, Wis.
RYDER, HARRY M., Research Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., Braddock Road, Wilkinsburg, Pa.
SATO, MASASHI, Electrical Engineer, Nagoya Electric Light Co. Ltd., Shinyanagi-Machi, Nakaku, Nagoya, Japan.
SCHLEICHER, GEORGE B., Tester, Philadelphia Electric Co. Laboratory, 226 So. 11th St., Philadelphia, Pa.
SCHMALZ, OTTO KARL, Asst. Electrical Engineer, B. F. Sturtevant Co., Hyde Park; res., 177 Colburn St., E. Dedham, Mass.
SCHULTE, THEODORE, Supt., Telephones & Electrical Equipment, Dept. of Natural Resources, Canadian Pacific Railway Co., Calgary, Canada.
SCHWEIZER, ALBERT C., Deputy Asst. Supt., New York Edison Co., 45 W. 26th St., New York, N. Y.
SCOTT, JAMES P., Engineer's Asst., Bell Telephone Company of Pennsylvania; res., 869 Lockhart St. N. S., Pittsburgh, Pa.
SCOTT, RALPH ALLEN, Lieut., U. S. Navy, Electrical Officer, U. S. S. Arizona, New York, N. Y.
SECKMAN, JOHN R., Sales Engineer, International Machinery Co., Casilla 107-D, Santiago, Chile, S. A.
SELF, WAYNE K., Electrician, Weirton Steel Co., Weirton, W. Va.; res., 622 North 5th St., Steubenville, Ohio.
SKINNER WILLIAM EUGENE; res., 545 Van Buren St., Milwaukee Wis.
SMALLIDGE, FRANK E., President & Manager, Electric Supply Co., 19 Wenatchee Ave. South, Wenatchee, Wash.
SMITH, D. BOYD, Asst. to Electrical Engineer, Nevada Consolidated Copper Co., McGill, Nev.
SMITH, JOSEPH W., Electrical Engineer, Colombia Products Co., Cartagena, Colombia, S. A.
SOUTHGATE, IRVING J., Foreman, Eastman Kodak Co., Kodak Park; res., 474 Flower City Park, Rochester, N. Y.
ST. CLAIR, HARRY, Signal Engineer, Chattanooga Railway & Light Company, Chattanooga, Tenn.
SUBERS, C. VAN ARTSDALEN, Asst. Electrical Designer, The Philadelphia Electric Co., Philadelphia; res., Ashbourne, Pa.
THOMAS, HUGH M., Asst. Supt., Gatun Locks, Gatun, C. Z.
THOMPSON, CHARLES S., Switchboard Operator, 925 W. 9th St., Wilmington, Del.
THOMPSON, THEO W., Asst. Foreman, Allis-Chalmers Mfg. Co.; res., 434 64th Ave., W. Allis, Wis.

Trompen, Nicholas J., Chief Cable Inspector, Brooklyn Edison Co., 360 Pearl St.; res., 1320 73rd St., Brooklyn, N. Y.
Tseng, Chou C., Electrical Engineer, Peking Chinese Electric Light & Power Co., Peking, China
Turley, Lester J., Engineer of Electric Power, Chief Engineer's Dept., Los Angeles Railway, 747 Pacific Electric Bldg., Los Angeles, Cal.
Tuttle, Walter William, Electrical Draftsman, Public Works Dept., U. S. Naval Station, Pearl Harbor, T. H.
Underwood, Cecil H., Railway Equipment Engineering Dept., General Electric Co., Schenectady, N. Y.
Vodicke, Frank J., Draftsman, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 101 W. Hutchinson St., Edgewood, Pa.
Wagner, C. E., Shop Foreman, Portland Railway Light & Power Co.; res., 1068 E. Morrison St., Portland, Ore.
Watson, Leon A., Draftsman, Electric Controller & Mfg. Co., 2700 E. 79th St., Cleveland, Ohio.
Waugh, Louie E., Electrician, Production Dept., Detroit Edison Co., Dehay Plant; res., 244½ Casgrain Ave., Detroit, Mich.
Webster, Clarence A., Senior Electrical Inspector, United States Shipping Board, Hog Island; res., 2522 So. 58th St., W. Philadelphia, Pa.
Webster, Marshall, Equipment Engineer, Western Electric Co., Chicago; res., 156 N. Oak Park Ave., Oak Park, Ill.
Wessels, Louis H., Electrician, Federal Shipbuilding Co., Kearny; res., 105 Union St., Jersey City, N. J.
West, Austin W., Resident Engineer, Lockwood, Greene & Co., 1530 Healey Bldg., Atlanta, Ga.
Westlake, Sherwood V., Electrical Tester, General Electric Co., River Works, West Lynn; res., Nahant, Mass.
Whiteman, Ralph A., Engineering Dept., Pennsylvania Public Service Corp., Johnstown; res., 201 N. 2nd St., Clearfield, Pa.
Widrig, John C., Salesman, A. H. Cox & Co.; res., 1132 8th Ave. West., Seattle, Wash.
Williams, Floyd E., Chief Electrician, Stambaugh Iron Co., Morton Mine; res., 132 Center St., Hibbing, Minn.
Williamson, Harold P., Salesman, Westinghouse Elec. & Mfg. Co., 111 W. Washington St., Chicago, Ill.
Winter, Parker D., Electrical Engineer, Wenatchee Battery & Motor Co., 7 Palouse St., Wenatchee, Wash.
Woidill, Julius A., Jr., Chief Electrical Draftsman, American International Shipbuilding Corp., Hog Island Shipyard, Philadelphia, Pa.
Wolfe, Nelson B., Wolfe & Joyce, 150 Nassau St., New York, N. Y.
*Wood, Harold B., Lineman, The Montana Power Co., Roundup, Montana.
Woodcock, Vincent J., Manager of Electric Fixture & Appliance Dept., Economy Electric Co., 22 Foster St., Worcester, Mass.
Wright, Vernon Radford, Manager, Wenatchee Battery & Motor Co., 7 Palouse St., Wenatchee, Wash.
Young, Dillard M., Erecting Engineer, Westinghouse Elec. & Mfg. Co., 6905 Susquehanna St., Pittsburgh, Pa.
Total 165
*Former enrolled students.

ASSOCIATES RE-ELECTED AUGUST 12, 1920

Fleming, Samuel W., Jr., Member of Firm, Gannett, Seelye & Fleming, 204 Locust St., Harrisburg, Pa.
Garratt, Graham L., Electrical Draftsman, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont.
Hund, August, Research Work, 1635 La Loma Ave., Berkeley, Cal.
Morphet, Frank K., Electrician, Vanadium-Alloys Steel Co., Latrobe, Pa.
Muldaur, George B., General Agent, Underwriters Laboratories, 25 City Hall Place, New York, N. Y.
Mulholland, Brendan F., Municipal Engineer, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont.
Punga, Franklin, Electrical Engineer, Hamburg Germany.
Radbone, Victor J., Sales Engineer, International General Electric Co., 83 Cannon St., London, E. C. 4, Eng.
Starkey, William C., Chief of Engineering Depts., The Ohio Brass Co., Mansfield, Ohio.

MEMBERS ELECTED AUGUST 12, 1920

Goldschmidt, Charles, Director a la Compagnie Generale d'Enterprises Electriques, 20 rue du Laos, Paris, France.
Johnson, Tomlinson F., Jr., General Electrical Supt., Georgia Railway & Power Co., 452 Electric & Gas Bldg., Atlanta, Ga.
Lynette, Harold A., Commercial Engineer, Westinghouse Elec. & Mfg. Co., 2133 Conway Bldg., Chicago, Ill.
Peck, Henry S., Sales Engineer, A. H. Cox & Co; res., 1612 Boylston Ave., Seattle, Wash.
Shoemaker, Guy T., Electrical Engineer, United Light & Railways Co., 125 W. 3rd St.; res., 916 E., 14th St., Davenport, Iowa.
Tait, Andrew A., Asst. General Master Mechanic, Canadian Car & Foundry Co. Ltd., 120 St. James St., Montreal, Quebec, Can.
Taylor, Claude S., Power Sales Engineer, Electricity Dept.' Shanghai Municipal Council, Shanghai, China.
Taylor, Carl D., Sales Engineer, Westinghouse Electric & Manufacturing Co., Union Bank Bldg., Pittsburgh, Pa.
Weyman, Hugh E., Manager, Levis County Railway, Levis, P. Q., Canada.
White, Bryant, General Supt., Lighting & Power Dept., Roanoke Railway & Electric Co.; Lynchburg Traction & Light Co., Lynchburg, Va.
Wood, Thomas S., Switchboard Engineer, Westinghouse Elec. & Mfg., Co., 133 Candler Bldg., Atlanta, Ga.

FELLOW ELECTED AUGUST 12, 1920

Carter, Thomas, Chief Engineer, with J. H. Holmes & Co.; res., Dene View, Heaton Road, Newcastle-on-Tyne, Eng.

TRANSFERRED TO GRADE OF MEMBER AUGUST 12, 1920

Baker, Frank J., Vice-President, Public Service Co. of Northern Illinois, Chicago, Ill.
Baldwin, Robert L., Electrical & Mechanical Engineer, Burns & McDonnell, Kansas City, Mo.
Barnes, Donald C., Manager, Seattle Division, Puget Sound Power & Light Co., Seattle, Wash.
Barron, Jacob T., General Supt. of Production, Public Service Electric Co., Newark, N. J.
Batcheller, Willis T., Electrical and Mechanical Engineer, Seattle Municipal Light and Power System, Seattle, Wash.
Bennett, Claudius E., Asst. Chief Engineer, Riegos y Fuerza del Ebro, Barcelona, Spain.
Bergstrom, Carl O., Manager, Electrical Dept., B. F. Sturtevant Co., Hyde Park, Mass.
Brill, Oscar C., Office of Chief Engineer, American Telephone & Telegraph Co., New York, N. Y.
Brown, L. E., Superintendent, Springfield Light, Heat & Power Co., Springfield, O.
Durand, William F., Professor of Mechanical Engineering, Stanford University, Stanford University, Cal.
Evans, Clarence T., Development Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Evans, Llewellyn, Superintendent of Electric Works, City of Tacoma, Tacoma, Wash.
Ferris, Livingston P., Electrical Engineer, Dept. of Development & Research, American Telephone & Telegraph Co., New York, N. Y.
Gaffey, John J., Assistant Engineering Manager, Harry M. Hope Engineering Co., Boston, Mass.
Ghosh, Surendra N., Acting Chief Electrical Engineer, Tata Iron & Steel Co. Ltd., Jamshedpur, India.
Hill, William S., Supt. Light & Power, Springfield Gas & Electric Co., Springfield, Mo.
Hurley, Wallace P., Sales Engineer, Westinghouse Electric & Mfg. Co., New York, N. Y.
Kilner, Ralph H., Commercial Engineer, Westinghouse Electric & Mfg. Co., Chicago, Ill.
Koontz, John A., Jr., Electrical Engineer, Great Western Power Co., San Francisco, Cal.
McAlpine, Dougald D., Contract Engineer, Canadian General Electric Co., Toronto, Ont.
McKenzie, Daniel A., Asst. Engineer, Operating Dept., HydroElectric Power Commission, Toronto, Ont.
Miller, Alvin A., Manager, Power & Railway Divisions, Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Oetting, O. W. A., Chief Engineer, Willard Storage Battery Co., Cleveland, O.
Pace, Gordon, District Operating Engineer, Hydro Electric Power Commission of Ontario, Toronto, Ont.
Pearce, Walter C., Supt., Electric Dept., Syracuse Lighting Co., Syracuse, N. Y.
Prindle, Edwin J., Senior Partner, Prindle, Wright & Small, New York, N. Y.
Read, Ernest K., Circuit Breaker Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
Robley, Roy R., Operating Engineer, Portland Railway, Light & Power Co., Portland, Ore.

Smith, Harold L., Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Van Horn, Irving H., Physicist, Lamp Development Lab., National Lamp Works of General Electric Co., Nela Park, Cleveland, O.
Warner, Russell G., Instructor in Electrical Engineering, Yale University, New Haven, Conn.
Westman, Adolf J., Electrical Engineer, Montreal Tramways Co., Montreal, Canada
Zima, Ludwig A., Assistant Cable Engineer, Interborough Rapid Transit Co., New York, N. Y.

TRANSFERRED TO GRADE OF FELLOW AUGUST 12, 1920

Beeuwkes, Reinier, Electrical Engineer, Chicago, Milwaukee & St. Paul R. R. Co., Seattle, Wash.
Fernow, Bernhard E., Jr., Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Morton, Robert B., Electrical Engineer with Toltz, King & Day, St. Paul, Minn.
Murphy, George R., Manager, Pacific District, Electric Storage Battery Co., San Francisco, Cal.
Pierce, Arthur G., Manager, Central District, Cutler-Hammer Mfg. Co., Pittsburgh, Pa.
Rice, Ralph H., Principal Assistant Engineer, Board of Supervising Engineers, Chicago, Ill.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held on July 26 and August 9, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

Recommended by Board of Examiners July 26, 1920 To Grade of Fellow

Lundy, Ayres D., Member of Firm, Sargent & Lundy, Chicago, Ill.
Stevens, William C., Sales Manager, The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

To Grade of Member

Anderson, Stewart W., Adjunct Prof. of Elec. Engg., Virginia Military Institute, Lexington, Va.
Andrews, Samuel W., Asst. Plant Engr., Niagara Power Development, Hydro-electric Power Commission, Niagara Falls, Ont.
Blalock, Grover C., Instructor in Electrical Engineering, Purdue University, Lafayette, Ind.
Boyajian, Aram, Development & Research Engineer, General Electric Co., Pittsfield, Mass.
Code, Elden S., Sales Engineer & Switchboard Designer, Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Costello, W. H., Sales Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Fawcett, Charles DeVan, Asst. Prof. of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.
Friday, Ellsworth C., District Manager, Corliss Carbon Company, Chicago, Ill.
Garlington, A. C., Supt. Construction & Maintenance, Elec. Div., Panama Canal, Balboa, C. Z.
Goetzenberger, Ralph L., Major, Ordnance Dept., U. S. Army, Frankford Arsenal, Philadelphia, Pa.
Hail, Joseph C., Electrical-Engineer-in-Charge, Dept. of Electricity, City of Chicago, Ill.
Knost, Chas. P., Salesman, Westinghouse Elec. & Mfg. Co., New Orleans, La.
Lund, Charles A., Distribution Engineer, Tacoma Light Dept., Tacoma, Wash.
McGrath, William H., Vice-President, Puget Sound Power & Light Co., Seattle, Wash.
Matthews, Howard D., Prof. of Elec. Machine Design, School of Engineering of Milwaukee, Milwaukee, Wis.
Mullen, Clyde A., Engineer of Tests, The Ohio Service Company, Coshocton, O.
Newton, John M., Chief Engineer, The Roland T. Oakes Company, Holyoke, Mass.
Olsen, Valdemar, Meter Engineer, Shanghai Municipal Council, Electricity Dept., Shanghai, China.
Oster, Eugene, Electrical & Mechanical Director, The Ault & Wiborg Co., Cincinnati, Ohio.
Owens, James W., Welding Aid & Asst. Shop Supt., U. S. Navy Yard, Norfolk, Va.
Rich, Edward P., Consulting Engineer, Chicago, Ill.
Rowe, E. C., Chief Draftsman, Commonwealth Edison Company, Chicago, Ill.
Sears, George C., Supt., White River Division, Puget Sound Power & Light Co., Dieringer, Wash.
Traver, O. C., Supervising Designing Engineer, Switchboard Dept., General Electric Co., Schenectady, N. Y.
Wegg, David S., Jr., Sales Engineer, Allis-Chalmers Mfg. Co., Chicago, Ill.
Wentworth, Herbert H., Industrial & Railway Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

Recommended by Board of Examiners August 9, 1920 To Grade of Member

Beird, Hobart B., Electrical Engineer, United Gas & Electric Engineering Corp., New York, N. Y.
Baldwin, John R., Electrical Engineer, Republic Flow Meters Co., Chicago, Ill.
Dustin, Fred G., President, Standard Electric Service Co., Minneapolis, Minn.
Goddard, Ralph W., Dean of Engineering, Professor of Electrical Engineering, New Mexico College of Agriculture & Mechanic Arts, State College, N. M.
McBrian, Edward W., Mechanical Engineer, Fox Bros. & Co., New York, N. Y.
Parker, Samuel R., Engineer of Plant, Saskatchewan Government Telephones, Regina, Sask.
Radbone, Victor J., Sales Engineer, Int'l. General Electric Co., London, England.
Shoemaker, Joseph J., Supt. of Public Utilities, Town of Sibley, Sibley, Ia.
Tolman, Clarence M., Moose Mountain, Ltd., Sellwood, Ontario
Wilson, N. P., District Service Manager, Westinghouse Elec. & Mfg. Co., Seattle, Wash.

APPLICATION FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member, objecting to the election of any of these candidates should so inform the Secretary before September 30, 1920.

Adams, Willard C., (Member), Chicago, Ill.
Alexander, Lowell M., Cincinnati, Ohio
Alexander, Roland B., Akron, Ohio
Alt, Milo S., Cedar Rapids, Ia.
Ames, Norman B., Akron, Ohio
Ammann, Philip G., New York, N. Y.
Anton, George, Lannett, Ala.
Barlow, Godfrey F., Toronto, Ont.
Beaudry, J. Armand, Worcester, Mass.
Beckenbach, Francis H., Schenectady, N. Y.
Bertrand, Philip A., (Member), Aberdeen, Wash.
Brown, Michael J., New York, N. Y.
Brownstead, John P., Ashland, Ky.
Budd, Chester E., New York, N. Y.
Butler, W. H., (Fellow), Philadelphia, Pa.
Cole, George H., Akron, Ohio
Cox, George R., New York, N. Y.
Daymude, John F., Cleveland, Ohio
de Forest, Charles S., New Haven, Conn.
Dyer, Franklin M., Boston, Mass.
Eldredge, William S., Chicago, Ill.
Evans, Earl R., Washington, D. C.
Eyster, James A., Waterbury, Conn.
Ferris, Bentley R., Akron, Ohio
Fielder, George M., New York, N. Y.
Green, Stanley S., W. Lafayette, Ind.
Henningsen, Earle S., Schenectady, N. Y.
Hefner, W. Albert, New York, N. Y.
Hempton, Frank, Gallup, New Mexico
Jones, David Clarence, Jr., Atlanta, Ga.

Key, Antonio E. Toro, Washington, D. C.
Kramer, Charles H., Cincinnati, Ohio
Krause, Joseph F., Milwaukee, Wis.
Leach, George M., Atlantic City, N. J.
Lewis, Ralph, New York, N. Y.
Malkin, Louis, Brooklyn, N. Y.
Matsuda, Saichi, E. Pittsburgh, Pa.
McGee, Robert F., Raleigh, N. C.
Miller, Andrew McR., Paris Island, S. C.
Miller, W. Webster, (Member), New York, N. Y.
Milliken, Earle L., Woonsocket, R. I.
Moore, Louis D., St. Louis, Mo.
Nakamura, Ichiro, New York, N. Y.
Peck, A. D., (Fellow), Beverly, Mass.
Piasecki, Harry A., Buffalo, N. Y.
Prack, J. Bernard, St. Louis, Mo.
Quinn, R. C., Atlanta, Ga.
Ryan, James A., Brooklyn, N. Y.
Schrumm, Jewett F., Waterbury Conn.
Seldin, William, Coney Island, N. Y.
Schilling, Eugene W., Akron, Ohio
Sitterle, Emil, Cleveland, Ohio
Smith, B. F., Atlanta, Ga.
Spilver, Fred W., Los Angeles, Cal.
Tadlock, J. H., Schenectady, N. Y.
Tonnesen, Sigvald, Hyde Park, Boston, Mass.
Weaver, George S., St. Louis, Mo.
White, E. Sherman, Long Island City, N. Y.
Wolfe, John F., Lancaster, Pa.
Wolle, James L., Philadelphia, Pa.
Total 60.

Foreign

Buttner, Harold H., Bordeaux, France
Doi, Masaji, Fukuokaken, Japan
Hattori, Katsuo, Kanasugi, Shiba, Tokio, Japan
Hayashi, Seiichiro, Marunouchi, Tokio, Japan
Horley, R. E. (Member), Southampton, England
Imai, Masakazu, Darien, Manchuria
Isono, Tatsuichiro, Kanasugi, Shiba, Tokio, Japan
Jones, Roy Stuart, Rubgy, Eng.
Komaru, Toda, Kobe, Japan
List, Vladimir, Brni, Czechoslovakia
Nakano, Yoshio, Muronan, Japan
Navarro, Justo Lopez, Manila, P. I.
Okada, Hisashi, Kanasugi, Shiba, Tokyo, Japan
Tojo, Kiichi, Kanasugi, Shiba, Tokyo, Japan
Trewman, Harry F., Woolwich, London, Eng.
Total 15.

STUDENTS ENROLLED AUGUST 12, 1920

11656 Lorenzo, A. de la L., School of Engg. of Milwaukeee
11657 Havlick, Joseph, School of Engineering of Milwaukee
11658 Fordham, Lyle, School of Engineering of Milwaukee
11659 Scudder, Felix W., University of Colorado
11660 Kerr, Francis, P., University of Colorado
11661 Clarke, Thomas H., University of Colorado
11662 Hutchinson, Halbert, Swarthmore College
11663 Kidd, Walter J., Pennsylvania State College
11664 Scott, Richard C., University of Michigan
11665 Crapo, Frederick M., Mass. Institute of Technology
11666 Martin, John J., Carnegie Institute of Technology
11667 Casey, Harry J., Johns Hopkins University
11668 Kemmeter, Bernard G., Tri-State College
11669 Glacy, Edward W., Tri-State College
11670 Bailey, Herbert R., Tri-State College
11671 Frazee, Floyd LeR., Armour Inst. of Technology
11672 Strong, Lewis B., Pratt Institute
11673 Seitanides, George B., Robert College
11674 Selpien, Carl W. H., Ohio Northern University
11675 Arbuckle, James S., McGill University
11676 Graf, Frank G., Pratt Institute
11677 Walmsley, George, Mass. Institute of Technology
11678 Huse, Walter D., New Hampshire College
11679 Thompson, Trevo C., McGill University
11680 Morgan, Robert B., Sheffield Scientific School
11681 Hendy, John W., Pratt Institute
11682 Ruge, Henry P., Lewis Institute
11683 Albert, Rudolph M., Columbia University
Total 28.

OFFICERS of A. I. E. E. 1920-1921

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(Term Expires July 31, 1921)

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FRANK D. NEWBURY

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F. F. FOWLE
L. F. MOREHOUSE

(Terms expire July 31, 1924)
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JAMES F. LINCOLN
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Edward Weston, 1888-9.
Elihu Thomson, 1889-90.
*William A. Anthony, 1890-91.
Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
Carl Hering, 1900-1.
Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
Schuyler Skaats Wheeler, 1905-6.
Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Kewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.

*Deceased.

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Economic Study of Secondary Distribution

BY P. O. REYNEAU
AND
HOWARD P. SEELYE

Both of the Detroit Edison Company.

Introduction

In working toward the efficient and economical design of the central station system as a whole no link in the chain connecting the consumer with the coal pile may be overlooked. The ultimate purpose of all study in this direction is to enable energy to be delivered to the customer at the least possible cost per unit, while at the same time good service is maintained. To this purpose considerable attention has been paid to generating plant, transmission lines and substations, but on the final link before reaching the customer—the distribution lines—the tendency has been to apply "rule of thumb" methods and "experience" only to the layouts. When it is considered that even in a well designed system the investment in distribution lines will often be from one-fifth to one-fourth of the total investment on the system and that the energy losses on these lines will be equal to or somewhat more than one-half of the total loss between the generator and the customer, it may be expected that a study of the economical design of distribution lines will be found of great profit. Such has been found to be the case, and the results of the study of secondary distribution described in this paper have been already applied to good advantage in the layout of such lines.

There are several conditions pertaining to the secondary system which make the careful layout of such a system especially important. The number of transformer installations is so large and the lines spread over so great an area that constant or even frequent inspection is impossible. The load is subject to irregular increases. In districts which are newly built up, new services are constantly being added. In old districts, new appliances are being purchased and the load on old services thereby increased. On this account any design must be made to cover a period of years and the increase in load for that period estimated from past experience. On the other hand, care must be taken not to install too much capacity and thereby increase the cost beyond the limits of economy. The problem must be carefully studied to obtain the balance between low cost and good service for any particular case.

In general the problems most often encountered are of the following types:

1. New lines in thinly populated districts where the load will probably build up rapidly.
2. Old lines in residence districts well built up where revision is necessary to care for a slowly increasing load.
3. Old lines in districts with heavy, increasing load such as business districts.
4. Exceptional installations such as for permanent loads with no increase or for a decreasing load.

In attacking such a problem we can often determine from tests and from past experience what the density of the loading is and how it will increase for some years in advance. We are usually limited to certain stock sizes of transformer and of wire, on any system, due to practical considerations of manufacturing and stock keeping. The problem then is to determine the proper combination of wire, transformer and transformer spacing in order to give good conditions of operation and also to show the least cost per year for the load densities expected during the period of time under consideration.

The purpose of this paper then is to study from an economical viewpoint the conditions generally met with in secondary distribution and to furnish as far as possible guidance for the designer to aid him in any particular problem with which he has to deal. It is clearly understood that no definite rules can be established which will fit all conditions. The variations in the problem are too many. The most that can be done is to furnish means for readily discovering the limitations of any problem and of proceeding within these limitations to the most economical design.

The study has been carried forward from three different angles. First from the theoretical; second from a semi-practical, that is by adopting certain standards and studying their behavior; third from

a purely practical, giving the designer data on the operation of various transformers and wire sizes under the conditions ordinarily encountered in practise.

In all this discussion it has been assumed that the loading is such that it may be considered as uniformly distributed along the line. The unit used is called load density, given in kilowatts per thousand feet. The line is assumed to be three-wire secondary, spaced 42 in. between outside wires. The cost of right-of-way, poles, cross arms and insulators is not included in any of the computations as it is assumed this would be the same under any given condition. Also the difference in length of primary for different transformer spacings is not considered. In actual design under known conditions a correction should be made for this. The loading conditions are taken as those of residence lighting districts although the same methods could be adapted to any other conditions of loading if its characteristics were known. Transformers are assumed to be in the center of the secondary served, feeding both ways. The symbols used and all the mathematical calculations will be found in Appendix A and B. Only the discussion will be presented here.

Discussion of Methods Used in Deriving Equations and Their Application

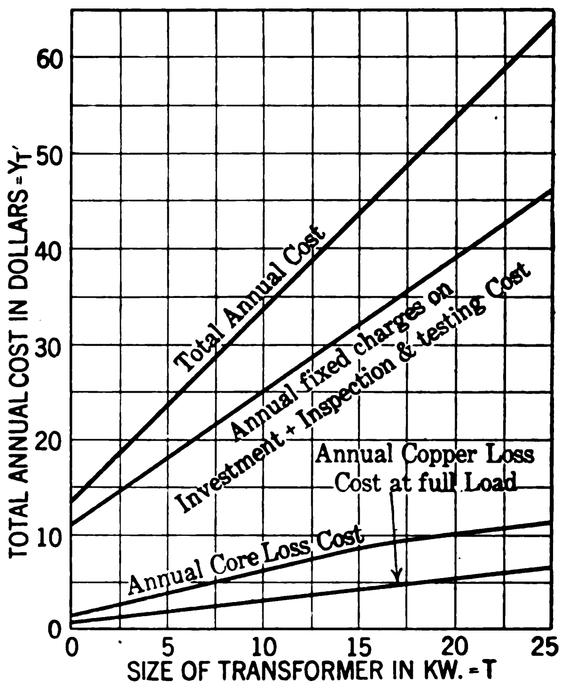
Theoretical. In the theoretical discussion ideal conditions are assumed which will rarely if ever be met with in practise, but it can be shown by a study of the results how they may be applied to practical conditions. These assumptions are that the line is indefinite in length so that the transformers may be placed at any exactly determined spacing and that the spacing will change with the load; that the transformer is always of a size just equal to the load to be carrried, that is equal to the load density at peak load times the spacing; that the wire may be of any cross-sectional area and vary with the load. Such a condition could only be obtained in a case where the load showed only seasonal variations and no yearly increase. However, in practise we usually design for a certain period at the end of which it is assumed the load density will be a certain amount.

The general method has been to obtain an expression for the annual cost per 1000 feet of line and to determine, by finding the first derivative and setting it equal to 0, the condition under which this annual cost is a minimum. This is the most economical condition.

Annual Cost of Secondary Distribution. The general equation for the annual cost is first obtained as follows: (Total annual cost per 1000 ft.) = (Annual Cost on transformers per 1000 ft.) + (Annual Cost on line per 1000 ft.)

$$Y = Y_t + Y_L$$

The annual cost on transformers must include interest, depreciation, insurance and taxes on the investment represented by the transformer in place. This investment is made up of the purchase price, plus freight and warehouse charges, plus cost of installation including lightning arresters, etc. It also includes the cost per year of inspecting and testing and the cost of energy losses. The core loss is practically a constant quantity for 24 hours per day throughout the year. The copper loss on the other hand depends on the load. If the characteristic variation of this load from hour to hour, day to day and month to month is known, the average loss per day can be determined in terms of the year's peak load. In this case the peak load is assumed to be just equal to the capacity



Curve No. 1—Annual Charges on Transformers
Transformers assumed to be fully loaded at yearly peak load.
Curve of total cost approximates equation
$Y_T' = K_1 + K_2 T$

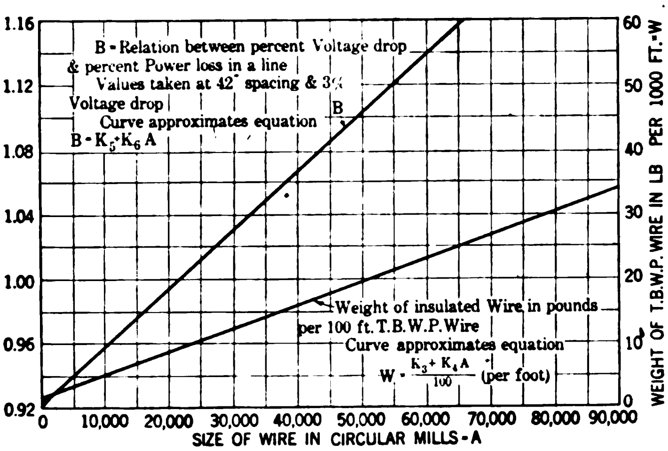
of the transformer. The cost of energy at the transformer must also be carefully determined. The cost for copper loss will be considerably higher than that for core loss on account of the lower load factor. The sum of all these items makes up the annual cost on a transformer.

It was found that if the value of the transformer annual cost is plotted against the transformer size that the curve for values between 0 and 25 kw. may be approximated by a straight line of the formula $Y_T, = K_1 + K_2 T$, T being the transformer size and K_1 and K_2 constants to be determined for any particular combination of transformer cost, energy cost, etc. (See curve No. 1.) This becomes $Y_T = \frac{1000}{S}(K_1 + K_2 T)$ per 1000 ft., where S is the length of secondary belonging to any one transformer or the distance between transformers where banked.

The annual cost on the line includes interest, depreciation and taxes on the investment cost of the

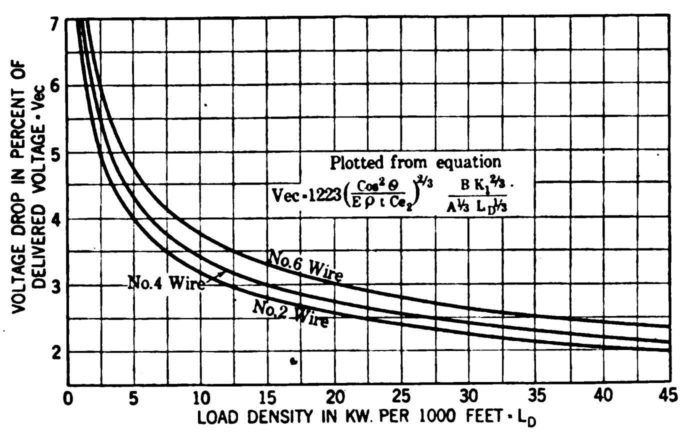
wire in place, including purchase price and cost of installation, also the cost of annual energy loss due to resistance. The copper loss is arrived at by the same method as the copper loss on the transformer, that is by use of the equivalent average number of hours per day at full load or equivalent hours.

The total annual cost per 1000 ft. of installation is now obtained by adding these two quantities, annual



Curves No. 2 and 3

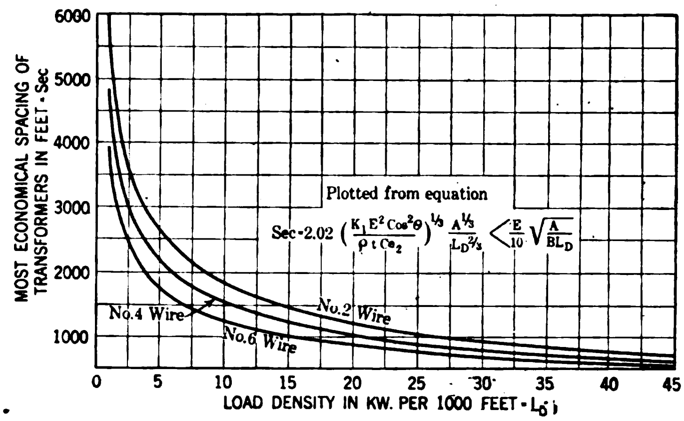
cost of transformers and annual cost on line, and the equation obtained as shown in equation (4)—(Appendix B) for Y in terms of S (length of secondary), L_D (load density), A and W (cross-sectional area and weight per foot of wire) and various constants to be determined by local conditions.



Curve No. 4—Most Economical Voltage Drop in Per Cent of Delivered Voltage

Load Uniformly distributed—Transformer size just equal to load.

Most Economical Voltage Drop. One of the most important controlling factors in determining the length of a secondary or the spacing of transformers is the maximum allowable voltage drop. It has usually been considered that the most economical condition of operation would be with a voltage drop higher than would be allowable for good service. In our case 3 per cent drop has been considered the limiting value, as luminosity curves for Mazda lamps show a reduction as high as 18 per cent with 5 per cent voltage drop while 3 per cent shows over 10 per cent reduction. Considering the voltage loss in the service drops which cannot be figured closely on account of variable conditions and the fact that the load is not absolutely uniformly distributed, 3 per cent is considered the



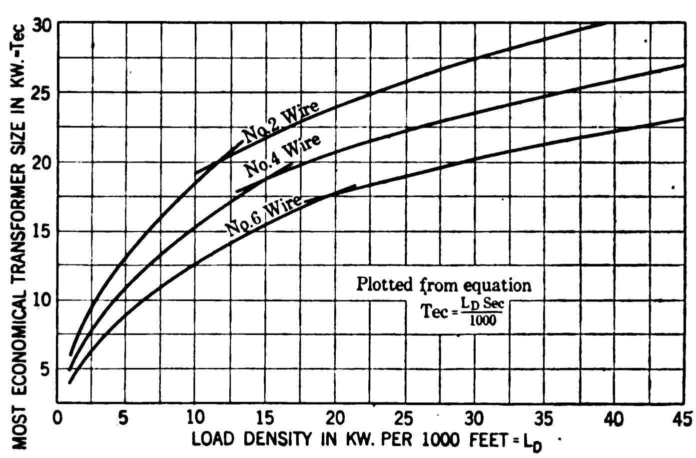
Curve No. 5—Most Economical Spacing of Transformers

Limited by a maximum allowable voltage drop of 3 per cent. Load uniformly distributed—Transformer size just equal to load

highest value commensurate with good operation. It must be determined, then, if under certain conditions, a smaller voltage drop than this will be more economical.

The expression for Y can be reduced to an equation in terms of L_D (load density), A. (cross-sectional area of wire), and V (per cent voltage drop). If this is then differentiated with respect to V and the first derivative set equal to 0, an expression is obtained for the most economical voltage drop in terms of wire size and load density. Equation (6). (Appendix B).

By assuming values for the constants to fit partic-



Curve No. 6—Most Economical Transformer Size

Being just equal to the load at the most economical spacing

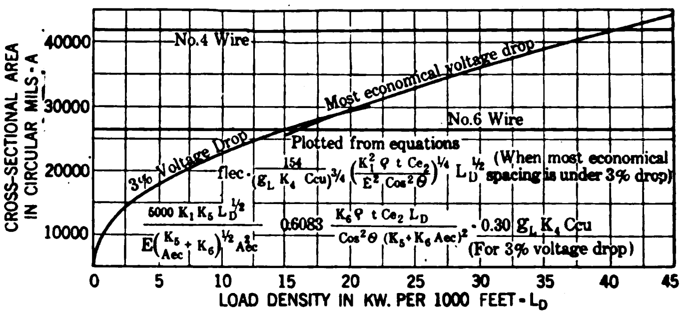
ular conditions this expression for V can be plotted against load density for various standard wire sizes. These curves show that, as load density increases, the most economical voltage drop decreases and under the conditions assumed in the curves here plotted, the

most economical voltage drop falls below 3 per cent at load densities which are often encountered with such loads, see curve No. 4.

Most Economical Transformer Spacing. In a similar manner it is possible to treat the question of length of secondary or transformer spacing. Equation (**4**) may be differentiated with respect to S (the transformer spacing). The first derivative is equated to 0 and we have the expression for the most economical spacing, equation (**7**). The transformer spacing however must be governed, for the smaller load densities, by the limiting voltage drop—taken here as 3 per cent. Hence equation (**8**) is derived which gives the spacing for a maximum voltage drop of 3 per cent. If now the constants are evaluated these curves may be plotted for various sizes of wire, using, for any particular load density, the equation which shows the shortest spacing. We obtain the set of curves No. 5 giving the transformer spacing which will give, with any wire size, the greatest economy, providing good operating conditions are maintained by having no voltage drop greater than 3 per cent.

Most Economical Transformer Size. It is a simple matter with these data at hand to derive the curves showing the most economical transformer size for any load density, providing the transformers are spaced most economically. Since it was assumed in the beginning that the transformer would be just large enough to carry the load, $T = L_D \frac{S}{1000}$ where S is the value taken from the curves for most economical spacing. This is the most economical size for any load since the annual charge on the investment represented by the transformer is a much greater proportion of the total annual charge than the cost of energy losses. Therefore the use of a larger transformer, even though under-loaded, would be more costly.

Most Economical Wire Size. It is now possible to attack the problem of the most economical size of wire for any load density. We will assume that it is feasible to use the most economical transformer size at its most economical spacing for any load density, modified by the limiting 3 per cent voltage drop requirement. Then if we substitute in our original equation, equation (**4**), the expressions for S used in plotting the curves for most economical spacing and for spacing limited by 3 per cent drop in voltage, we obtain two expressions for the annual cost per 1000 ft. in terms of load density and cross-sectional area of wire (A). Here it is necessary to introduce two approximations. The weight per foot of wire (w) enters the equation, also the quantity B which is the constant relation between per cent voltage drop and per cent power loss for any size of wire. It is found by plotting values of w for standard sizes of wire of the range of sizes which would be used in secondaries that the expression $w = K_3 + K_4 A$ is a very close approximation, K_3 and K_4 being constants (see curve No. 2). Also it is found that the value of B for any size of wire may be approximated very closely by the straight line function $B = K_5 + K_6 A$, where K_5 and K_6 are constants (see curve No. 3). These must be derived from the particular values of B which apply to the conditions being studied since these values vary for different spacings between wires. Substituting these expressions in the equations referred to above we obtain the two general expressions for annual cost per 1000 ft. in terms of wire size for maximum economy of transformer spacing and for 3 per cent voltage drop equations (**10**) and (**12**). These are now differentiated with respect to A and the equations (**11**) and (**13**) are obtained between the most economical wire size and the load density for most economical spacing and for 3 per cent voltage drop. The constants were evaluated and these curves plotted (No. 7), the 3 per cent curve for low load densities and the maximum economy curve



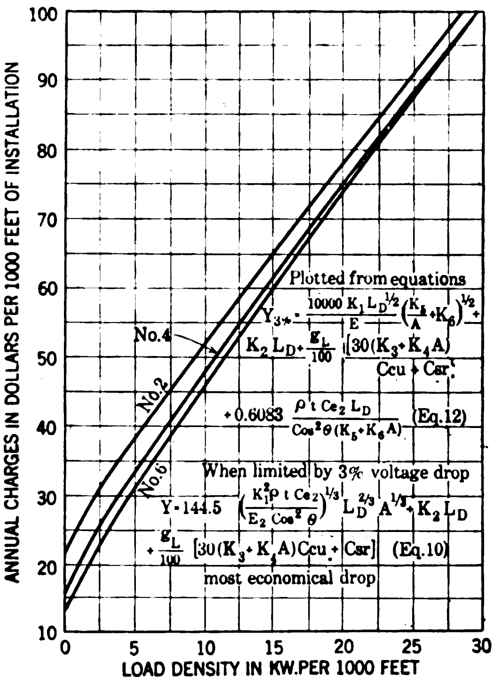
Curve No. 7—Most Economical Wire Size

Transformer size assumed just equal to load at most economical spacing limited by 3 per cent voltage drop

for high loading. They furnish a graphic representation of the most economical size of wire to use under any load density providing ideal conditions obtain in the way of transformer size and spacing.

Purpose of Theoretical Curves. At first glance it may appear as if these curves being obtained on the basis of such theoretical assumptions could have very little practical value. However, when attacking a practical problem of this nature the data from these curves may be used as the basis upon which to start the calculations of annual costs under operating conditions. If for example the present load density and the load density which is to be expected at some certain future time are known, by going to the theoretical curves we may determine (a) whether the voltage drop is to be limited by the 3 per cent maximum, (b) what would be the most economical conditions of transformer size and spacing for present operation and for operation at that future time, and (c) what standard size of wire will be most economical over the period. The curve for the most economical wire size covers, for each standard size, such a range of load densities that we should be able at once to select our wire size without further computation. Having determined this and

knowing what stock sizes of transformers and practical spacings come the nearest to fitting the ideal conditions over the period under consideration, we can then investigate, as will be shown later, the comparative economy of such various methods of installation as could be used in this particular case. In other words



CURVE No. 8—SHOWING COMPARATIVE ECONOMY OF VARIOUS WIRE SIZES IN SECONDARY INSTALLATIONS

Transformer sizes and spacings assumed to be those most theoretically economical, limited by 3 per cent maximum voltage drop.
Annual cost includes line and transformers.

these theoretical curves give certain limitations on which we may proceed to further more practical investigation.

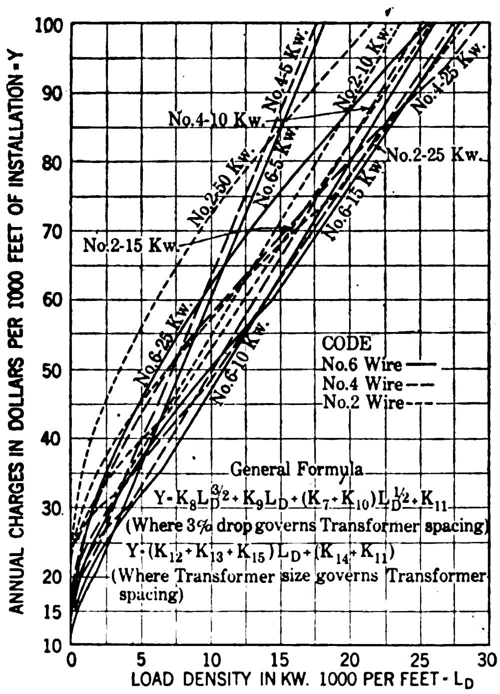
SEMI-PRACTICAL. In order to present our results in a little more concrete and practical form and to show the exact comparative economy between various types of installation, especially with respect to the size of wire to be used, a series of curves was developed showing the exact annual cost under various conditions. These are called the semi-practical curves. Curves No. 8 and No. 9.

Annual Cost of Standard Wire Sizes Working under Ideal Conditions. The first condition was assumed to be that in which the most economical size of transformer could be used, spaced the most economically or, where necessary, for 3 per cent maximum voltage drop. A curve was plotted for each of the three standard sizes of wire No. 6, No. 4 and No. 2, showing the annual cost at various load densities, (see curve No. 8). This is, in reality, simply plotting equations (**10**) and (**12**) as developed above.

Annual Costs per 1000 ft. of Installation for any Combination of Standard Sizes of Wire and Transformers. As the next step in proceeding from the general problem to the concrete example various combinations of standard sizes of transformers with standard sizes of wire were assumed and curves developed showing the annual cost of each of these combinations at various load densities. The transformer spacing was still assumed to be always the theoretically best spacing for each particular load. This enables us to compare for example the economy of a 10-kw. transformer and No. 4 wire with that of a 15-kw. and No. 6 wire at any load density.

The method of developing these curves has some points of interest although the equations are merely variations of our general equation for annual cost per 1000 ft. It is seen that for any size of transformer, as the load density increases a certain point is reached where the spacing is no longer governed by the allowable voltage drop but by the size of the transformer itself. Hence each curve will consist of two parts, the lower where the voltage drop governs the spacing, the excess transformer capacity is provided, the upper where the transformer size governs the spacing and the voltage drop is less than the allowable. The total annual cost is made up of five items.

1. Transformer core loss.
2. Transformer copper loss.
3. Copper loss on the line itself.



CURVE No. 9—SHOWING COMPARATIVE ECONOMY OF VARIOUS COMBINATIONS OF SECONDARY INSTALLATIONS

Load uniformly distributed.
Voltage drop most economical—maximum 3 per cent.

4. Fixed charges on the transformer (interest, depreciation, taxes, inspecting, tests, etc.)
5. Fixed charges on the line. (Interest and depreciation).

Each of these five elements was analyzed as to constants and variables, considering the load density L_D

as the chief variable, and the transformer and wire sizes constant for any given condition. It was found that the equations took the following form:

$Y = K_8 L_D^{3/2} + K_9 L_D + (K_7 + K_{10}) L_D^{1/2} + K_{11}$

when the voltage drop and wire size govern, and

$Y = (K_{12} + K_{13} + K_{15}) L_D + (K_{11} + K_{14})$

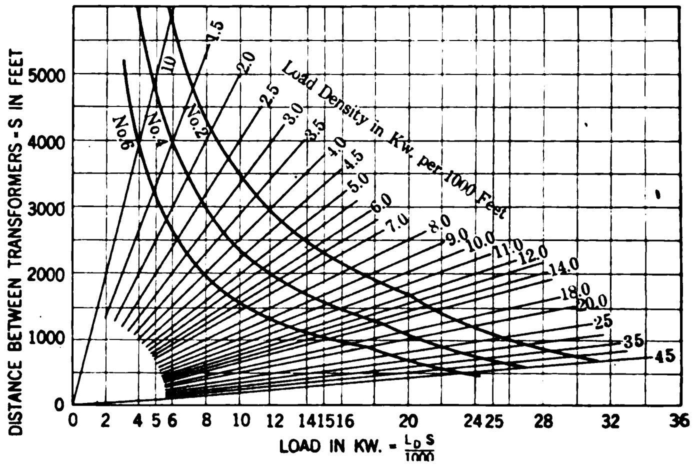
when transformer size governs.

The first is an equation of a third degree curve in $L_D^{1/2}$ breaking into a straight line (the second equation) at the critical point where the spacing for 3 per cent drop fully loads the transformer. The equation for each constant was then developed and evaluated for each combination of wire and transformer. The results were then plotted as shown in curve No. 9. The detailed derivation of these equations and constants has been omitted from the appendix as these are of less relative importance than the others given.

Purpose of Semi-Practical Curves. These semi-practical curves, although reducing the variable elements, still retain enough of the ideal condition so that they cannot be used as an absolute criterion but merely as a guide. They do show however, concretely, the relative economy of the various standard sizes of wire when used under the most favorable conditions and this may be taken as a guide to their comparative behavior under all conditions. The second set of curves also shows concretely the relative economy of the various transformer sizes with any one size of wire as well as the relative economy of various sizes of wire with any size of transformer. This comparison of economy is valuable in showing the exact amount by which the annual cost of one installation is greater or less than another. It often occurs that where the difference in cost is not great, other advantages are sufficient to more than offset it and lead to the choice of the more costly. The spacing of transformers is here considered to be the maximum allowable throughout, with the transformer carrying its maximum allowable load. This limits the general application of these curves in practise and hence like the first series they are chiefly useful in establishing limits and as a basis for the design.

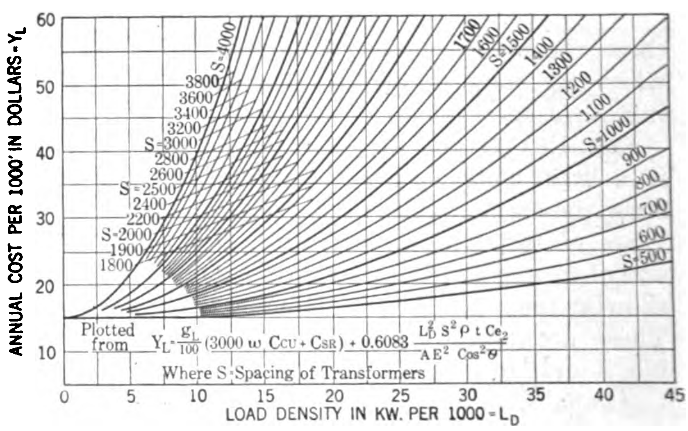
PRACTICAL. We now come to the development of the curves which the designer may use in testing the economy of any design and thereby choose the most economical from several alternatives. Here no "most economical" conditions need be assumed. The curves simply represent annual costs as they occur under any condition which may be encountered.

Load Curves for Secondaries. The first curve is a development from the two theoretical curves, the most economical transformer spacing and most economical transformer size. By plotting the transformer size against the spacing we obtain for each size of wire a curve showing the most economical spacing or the spacing limited by 3 per cent voltage drop for any total load on the transformer (see curve No. 10). By drawing diagonal lines, one for each load density desired, we can now show for any particular load density, the maximum economical spacing, and the minimum transformer size with that density and spacing. This curve merely simplifies the former two and serves the same purpose, not introducing any new principles. It is evident that any point below the curve will indicate a drop less than the value used on



CURVE NO. 10—LOAD CURVES FOR SECONDARIES
Three-wire secondaries—244/122 volts at customer.
Most economical transformer spacing limited by 3 per cent voltage drop.
Power factor 95 per cent —Load uniformly distributed—42-in. spacing between outside wires.

the curve. This curve is of use in determining what alternative designs may be feasible with any load and standard equipment and what changes may be made to care for an increase.

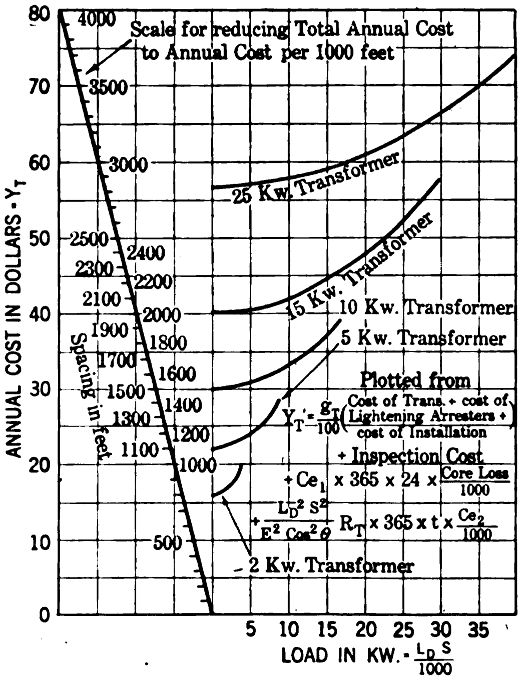


CURVE NO. 11—LINE COST CURVES
Annual cost per 1000 ft. of three No. 4 secondaries including fixed charges and cost of lost energy.

Line Cost Curves. The equation for annual charges on the line, (equation (3) Appendix B) was next developed. All constants were evaluated and a curve plotted for each desired spacing—100-ft. intervals were used—showing the annual charges per 1000 ft. in terms of the load density for each standard size of wire. (See curve No. 11 for No. 4 wire.)

Transformer Cost Curves. The third set of curves shows the annual cost on the transformer for any

loading, (see curve No. 12). This of course is equal to the fixed charges, plus the core loss cost which is constant for all loads, plus the copper loss cost which varies as the square of the load. The equation for each of the standard sizes of transformers, 2, 5, 10, 15 and 25 was developed and plotted. Since this curve shows total annual cost on a transformer and not cost per 1000 ft. of installation a scale was added on the diagonal at the left by use of which, with a pair of triangles, the cost per 1000 ft. may be obtained by the principle of similar triangles. Draw a line from the total cost obtained to the spacing as shown on the diagonal scale and a parallel through 1000 ft. will indicate the annual cost per 1000 ft. on the vertical scale. (See Appendix B for illustration.)



Curve No. 12—Transformer Cost Curves

Total annual cost on various sizes of transformers under various loads. Includes fixed charges and cost of energy losses.

Cost of Replacing Transformers. Two more items of cost are of interest to the designer and these are arbitrarily fixed by local conditions, the cost of changing the size of transformers in the same location and the cost of changing the location of a transformer. These will be practically constant for all sizes and may be determined in any case from local cost records.

Application of Practical Curves. We are now ready to furnish the designer with the information necessary to test the relative economy of any two alternative designs. He first determines his wire size from a study of the theoretical and semi-practical curves. Then, going to the load curves he may determine his alternatives in transformer size and spacing. Assume that conditions point to the alternative of installing 10-kw. transformers at a long spacing, changing to 15 kw. at a shorter spacing after a certain period of years, or of installing the 10 kw. at the shorter spacing now and merely changing sizes at that time. From our curves the exact cost per 1000 ft. for each year under consideration may be obtained by using the correct loading and spacing and, at the proper time, adding the cost of either changing location or changing size. The total of the annual costs for each design gives the total cost over the period under consideration and a comparison of the totals shows exactly the relative economy of the designs over the whole period. These curves may be applied to any such problem since they are based not on the assumption of ideal conditions but cover any actual condition which might occur in practise. They can be used in cases where the transformer spacing cannot be uniform on account of local conditions of pole spacing, secondary length, and street and alley arrangement, a very usual case. When there is doubt about the wire size a study of the various possible combinations making use of these curves will soon determine the size for greatest economy. Similar curves can also be developed to suit other classes of problems such as concentrated loads, loads with characteristic variations different from those of the residence load used here, as in business districts, power loads, etc.

Example of Application of Practical Curves. A concrete example of the use of the above curves may be helpful. Assume that tests on a district show a load density of 8 kw. per 1000 feet, with No. 4 secondary wire already in place. Our load curves show for that loading and size of wire, 12.8 kw. load at 1800-ft. spacing to keep within 3 per cent drop in voltage. We wish to provide for an increase in load which we will estimate may go to 15 kw. per 1000 ft. in six years. For the present a 10-kw. transformer spaced at 1400 ft. would care for the load while at 15 kw. per 1000 feet there would be required a 15-kw. transformer at 1000-ft. spacing or a 25-kw. at 1200 ft. In order to avoid too many changes we may space 10-kw. transformers at 1000 ft., changing in three years to 15 kw. or we may put in 15 kw. transformers now at 1500 ft., changing the location in two years to 1000 feet. Other alternatives might be considered but these two will serve as an example.

For the first alternative, assuming uniform increase in load density of 1 2/5 kw. per year.

	Per 1000 ft. installation	
1st year.		
Line Cost — L_D = 8 kw., S = 1000......	$16.00	
Transformer — Cost 10 kw. at 8-kw. load ..	32.00	
For year		$48.00
2nd year.		
Line Cost — L_D = 9 2/5 kw., S = 1000...	16.30	
Transformer Cost — 10 kw. at 9 2/5.......	32.70	
For year		$49.00

3rd year.		
Line Cost — L_D = 10 4/5 kw., S = 1000.	16.80	
Transformer Cost — 10 kw. at 10 4/5	33.70	
For year		\$50.50
4th year.		
Line Cost — L_D = 12 1/5 kw., S = 1000.	17.30	
Transformer Cost — 15 kw. at 12 1/5	42.90	
Cost of Changing Size (10 kw. to 15 kw. on same pole)	7.00	
For year		\$67.20
5th year.		
Line Cost — L_D = 13 3/5 kw., S = 1000.	17.80	
Transformer cost 15 kw. at 13 3/5	43.60	
For year		\$61.40
6th year.		
Line Cost — L_D = 15 kw., S = 1000	18.40	
Transformer cost — 15 kw., at 15	44.40	
For year		\$62.80
Total for 6 years		\$338.90
Second Alternative.		
1st year.		
Line Cost — L_D = 8 kw., S = 1500	17.20	
Transformer Cost — 15 kw. at 12-kw. load.	35.50	
For year		\$52.70
2nd year.		
Line cost L_D = 9 2/5 kw., S = 1000	\$18.00	
Transformer cost 15 kw. at 15 4/5	37.20	
Transformer Cost — 15 kw. at 12-kw. load.	35.50	
For year		\$55.20
3rd year.		
Line Cost L_D = 10 4/5 kw., S = 1000	16.80	
Transformer Cost — 15 kw. at 10 4/5	42.30	
Cost of changing location	20.50	
For year		\$79.60
4th year—same as 1st alternative (less charge for changing size)	60.20	
5th year—same as 1st alternative	61.40	
6th year " " " "	62.80	
Total for 6 years		\$371.90

A saving of \$33.00 per 1000 ft. of installation, or approximately 10 per cent of the total cost over a period of six years by the first method thus demonstrating its economy. It is well to note that a large part of the difference in cost is due to the fact that in the first case the size of transformer is changed while in the other the location but not the size is changed. If a further refinement of the comparison is desired, interest may be considered on the yearly items up to the end of the period under consideration. Usually such refinement is not necessary however.

CONCLUSIONS

A study of all these curves gives considerable aid in determining certain standards of design as well as the final particulars for any special problem. There also may be obtained a definite knowledge of the behavior of secondaries under various conditions of loading and operation. It is purposed here to take up each curve in detail, to bring out its characteristics and its possible use.

Most Economical Voltage Drop. The curves on voltage drop show that the most economical condition varies inversely as the cube root of the wire size also inversely as the cube root of the load density.

For low-load densities the economical drop is high but decreases rapidly, while at high loading the decrease is comparatively slow. It is clearly shown that the most economical voltage drop may be well under that allowable for good service for loads which may be often encountered in practise. Under the conditions and prices assumed in the present case the 3 per cent limit seems to have some justification by economy for ordinary loads.

Two conditions must be considered which might affect these curves, *i. e.*, the price of materials and cost of energy and the fact that here the transformer was considered just sufficient to carry the load while ordinarily, when designing for an increasing load, the transformers are underloaded. It is seen from the equation of the curves for economical voltage drop that the cost of copper does not affect this discussion. This is due to the fact that the annual cost is based on a unit of 1000 feet, hence for any given price of copper the annual cost per 1000 feet of three-wire line is a constant no matter what the load. The cost of energy enters as an inverse factor to the 2/3 power. Also it is a small element in the factor K_1, which is also to the 2/3 power but in the direct ratio. Hence an increase in the cost of energy would increase both the numerator and the denominator but the latter slightly more than the numerator, hence all the curves would be raised slightly. This effect would be small however for ordinary fluctuations. In the case of an increase in the transformer price there would be no change in the curves providing the increase were proportional to the size since the factor K_1 would not be affected by such an increase.

In ordinary design for an increasing load the transformer would be made larger than sufficient to carry the present load to allow for the anticipated increase. A study of the curves for the various components of the annual charge on a transformer and the equation resulting therefrom, Y_T, $= K_1 + K_2 T$, will show that if they are developed with the transformer working below its rated loading, and if the percentage of underloading is kept the same for all sizes, the factor K_1 will be very little affected, the effect being similar to an increase in price proportional to size. Since this is the only part of this equation that enters into the equation for most economical voltage drop it follows that if a design could be limited to any given percentage of underloading throughout, the curves would still show the most economical condition of voltage drop.

Most Economical Transformer Spacing. These curves for the most economical transformer spacing

(curve No. 5) are derived from the same general expression for annual cost per 1000 feet as those for economical voltage drop. Hence the same results might be expected from the use of either of these sets of curves with the exception that where the most economical spacing would give a maximum voltage drop of more than 3 per cent we have corrected it for that value making it such as to give 3 per cent.

These curves show for very low-load densities, extremely high spacings which are probably much greater than it would be practicable to use since for such a distance and such light loads the effect of the non-uniform loading would be considerable. As is shown by the equation, the spacing for 3 per cent drop varies as the square root of the wire size while for greatest economy it varies as the cube root. It also varies inversely with the load density, to the square root in the first case, the 2/3 power in the second. For ordinary loadings encountered in practise and the usual range of wire sizes it is seen that spacing of from 1000 to 2000 feet is the most economical and practicable. For the higher loadings the most economical spacing decreases very slowly, remaining over 500 feet up to high values of L_D.

Changed conditions would have a similar effect on these curves as on those for economical voltage drop, in the range of values for which the most economical voltage drop governs the spacing. That is, a rise in the price of energy would lower the curves slightly; the prices of wire and transformer would not have a noticeable effect. For the condition of underloaded transformers, if the proportion of underloading were fixed there would be slight change. In practical designing, however, when considering the amount of this margin in transformer capacity to be used, it might be found relatively more economical to use a transformer size somewhere near the theoretically most economical and obtain the margin in capacity by using a spacing less than the most economical spacing. This may have some advantage over using the most economical spacing, as shown by the curves, and a larger size of transformer than the most economical, when the design is to cover several years and the cost of changing sizes and locations is taken into account. Hence, care must be used in placing too much dependence on the strictly theoretical values in practical design. The choice must be tested by the actual year costs as shown by the cost curves.

Most Economical Transformer Size. The curves for the most economical transformer size simply show the size of transformer which will carry the load when the spacing is the most economical or just enough to give 3 per cent voltage drop. They have relatively less practical value excepting that it is from these and the spacing curves combined that the practical load curves are obtained.

Most Economical Wire Size. The wire size is the first thing to determine in a design and must be chosen to cover long periods of increase in load as replacement of secondary wire is very costly. Hence for secondaries a standard must be chosen for installation in new work which will show good economy through the greatest range of conditions to be encountered. The curves seem to indicate clearly that under the conditions and prices assumed No. 6 wire should be used as a standard in all new work, in districts where ordinary residence lighting load is expected. The economy curve rises very rapidly at low densities up to about 20,000 cir. mils or nearly to No. 7 at about 7 kw. per 1000 feet. From here the rise is less rapid but still considerable until it crosses the value of No. 6 wire at 15-kw. load density. The load density of 15 is a normal loading. It would not be advisable to use any size less than a No. 7 since the loadings at the smaller values are subject to such rapid increase. Even at No. 7 the economical load is fairly small (7 kw. per 1000 feet). On the other hand, the curve rises slowly after passing No. 6 and only reaches No. 5 at a loading of about 31 kw. and No. 4 at 40 kw. which are high densities and to be encountered only in special cases. It is interesting to note that for all values below a No. 6 wire the economical size is governed by 3 per cent voltage drop while above that the most economical drop governs the curves crossing at 19-kw. load density.

Since the curves were figured at a low copper price, in case of an increase in price, the curves would be lowered, *i. e.*, a smaller wire size would be indicated for any particular loading. An increase in energy cost would slightly raise the curve, an increase in transformer price if proportional to size would not affect the discussion. Since the curves were figured on the assumption that the transformer spacing was the most economical and the size just equal to the load, a change in these conditions might affect the most economical wire size somewhat. A fixed proportion of underloading as above shown would have little effect but if different conditions of spacing were assumed, the design should be tested by use of the cost curves for various sizes of the wire.

Semi-Practical Curves. The curves which we call semi-practical show a little more concretely the relative economy of installations with the various sizes of wire, in dollars per year per 1000 feet. They show the actual annual cost for different types. The excessive cost of No. 2 wire for ordinary loads is clearly demonstrated being from \$3.50 to \$6.00 per year more than No. 4 for loadings up to 15 kw. per 1000 feet.

When we go from the ideal size of transformer to practical stock sizes, still assuming the best spacings to be used, there are some conditions in which the relative wire economy is somewhat different. These curves also give an indication of transformer economy. It seems to be quite clearly shown that, under the assumed conditions, the use of large transformers such as 25-kw. is not justified except with very heavy

loading, even considering the possible reduction in the number of transformers and hence in the core loss. The increase in the investment cost more than equalizes such saving.

Practical Curves. The use of the cost curves in designing has already been explained. It may now be readily seen how a study of the theoretical and semi-practical curves applied to any problem will give a basis upon which to formulate a design which can then be tested for actual economy by application of the exact costs to be expected. We can determine from this, in case of a new line, the size of wire and then the spacing and size of transformers which will care for several years of increase. The exact number of years will be determined by the rate of increase together with the economy of the design, including cost of changing sizes and locations. Or, in case of remodeling an old district, we start with a given size of wire which although perhaps not the most economical, will not justify the cost of change. We can then choose and space our transformers most economically with regard to that size of wire. In a special case where no increase in load is expected the theoretical curves will give exactly the design to use. In other cases where the loading, voltage, etc., are somewhat different, by proper substitution in the theoretical formulas, curves could be plotted which would apply to that particular condition.

General. The curves given here should not be accepted for general application to design problems. The costs and conditions of loading used were of local derivation and apply only to the organization and the time for which they were obtained. Similar curves should be developed for the study of conditions in any other locality and they should be revised from time to time to meet changing conditions. These examples are given here merely to indicate the characteristics of such curves.

It is evident that no very simple means of correctly designing a distribution system in regard to transformers and secondary wire can be made available due to the many varying conditions encountered and the large number of factors to be taken into account.

The elements of good judgment and experience are as necessary in the solution of these problems as in any other problem of engineering. The object of this study has been to analyze and evaluate the factors of the design of the secondary system that lend themselves to such definite analysis and to present the results as aids in the application of good judgment and experience to the best possible solution of the problem.

In conclusion the authors acknowledge gratefully the assistance of Mr. Harold Cole and Mr. Lansing W. Thoms in the preparation of this paper.

APPENDIX A

TABLE OF SYMBOLS

The following is a list of the principal symbols used, with their general definitions. In Appendix B, the significance of each symbol will be explained for the individual case under consideration.

A = cross-sectional area of wire in circular mils.
A_{ec} = most economical cross-section of wire in circular mils.
B = constant relation between per cent voltage drop and per cent power loss.
C_{cu} = cost of insulated copper wire per lb.
C_{e1} = " " core loss per kw-hr. at transformer.
C_{e2} = " " copper loss per kw-hr. at transformer and secondary.
C_{sr} = cost of stringing wire per 1000 ft. of line.
E = Secondary receiver voltage between outside wires.
g = per cent interest, depreciation and taxes (g_t on transformer, g_L on line).
I = total current on secondary.
$K_1, K_2 \cdots K_n$ = the numerical constants.
L_D = load density in kw. per 1000 ft.
R_T = equivalent resistance of transformer in ohms
R = resistance in ohms.
S = spacing of transformers in feet.
S_{ec} = most economical spacing of transformer.
T = size of transformers in kilowatts.
T_{ec} = most economical size of transformer in kilowatts.
t = equivalent hours per day in terms of yearly peak load to give a total energy loss equal to the actual.
V = per cent voltage drop.
V_{ec} = most economical per cent voltage drop.
W = total load on secondary in watts.
w = weight per foot of insulated wire in lb.
Y = total yearly cost per 1000 feet of installation.
Y_T = total yearly cost of transformer per 1000 ft. of installation.
Y_T' = total cost yearly per transformer.
Y_L = total yearly cost of line per 1000 ft. of installation.
Y_L' = total yearly cost of line for given spacing.
Cos θ = power factor of load.
ρ = resistivity of wire in ohms per mil-foot.

APPENDIX B

DERIVATION OF FORMULAS

List of Fundamental Assumptions:

1. Continuous three-wire secondary.
2. Uniformly distributed load.
3. Difference in cost of primary wire and copper loss in primary for different spacing of transformers neglected.
4. Cost of poles, cross arms, pins, insulators and right-of-way same for all cases and hence omitted from discussion.

These four assumptions are carried through the entire study. Any additional assumptions are stated in the derivation of the individual formula.

A. DEVELOPMENT OF THE THEORETICAL CURVES

1. *Annual Cost of Secondary Distribution.*

Annual cost per 1000 feet of installation = Y

Y = (Total annual charges on transformers per 1000 ft. of line) + (total annual charges on line per 1000 ft. of secondary)

$= Y_T + Y_L$ (1)

Where $Y_T = \dfrac{\left(\dfrac{g_T}{100}\text{(purchase price + cost of handling + Cost of installation + cost of lightning arresters and equipment) + cost of core and copper loss + cost of inspection}\right)}{\dfrac{1000}{S}}$

g_T = per cent interest + depreciation + taxes on transformer.

S = spacing of transformers in feet.

Y_T -- can be expressed as a function of the transformer size, T, as follows:

$$Y_T = \frac{1000}{S}(K_1 + K_2 T)$$

Where K_1 and K_2 are constants and are found by plotting total annual charges on transformer against transformer size. (See curve No. 1.)

Assuming a transformer size just sufficient to carry the load, then $T = L_D \dfrac{S}{1000}$.

Where L_D = load density in kw. per 1000 ft.

$$\text{Then } Y_T = \frac{1000}{S}\left(K_1 + K_2 \frac{L_D S}{1000}\right) \qquad (2)$$

Y_L = investment cost of material per 1000 ft. of line + installation charges per 1000 ft. of line $+ \dfrac{1000}{S} \times$ cost of copper loss in secondary.

$$Y_L = \frac{g_L}{100}(3 \times 1000 \times w \times C_{cu} + C_{sr}) + \frac{1000}{S}\left[2\left(\frac{I}{2}\right)^2 \times \frac{\rho}{A} \times \frac{S}{6} \times 2 \times t \times 365 \times \frac{C_{e2}}{1000}\right]$$

Where

g_L = per cent interest + depreciation + taxes on line.

w = weight of insulated wire in lb. per foot.

C_{cu} = cost of insulated wire per lb.

C_{sr} = cost of stringing 1000 ft. of line.

I = total current in secondary at transformer.

ρ = resistivity of wire per mil-foot.

C_{e2} = cost of copper loss in secondary per kw-hr.

t = equivalent hours per day which yearly peak load should continue in order to give an $I^2 R$ loss equal to the total actual $I^2 R$ loss for the year.

A = cross-sectional area of wire in circular mils.

E = voltage between outside wires of secondary.

$\text{Cos } \theta$ = power factor of load.

$$I = \frac{L_D S}{E \text{ Cos } \theta}$$

and

$$Y_L = \frac{g_L}{100}(3000\, w\, C_{cu} + S_{sr}) + S^2\left[\frac{L^2_D}{E^2 \cos^2\theta} \times \frac{\rho}{A} \times t \times 60.83\, C_{e2}\right] \qquad (3)$$

$$\text{Then } Y = \frac{1000}{S}\,\frac{(K_1 + K_2 L_D S)}{1000} + \frac{g_L}{100}(3000\, w\, C_{cu} + C_{sr}) + S^2\,\frac{(60.83\, L_D^2\, \rho\, t\, C_{e2})}{A\, E^2 \text{ Cos } \theta} \qquad (4)$$

Equation (4) gives the total annual cost per 1000 ft. of installation as a function of the spacing and load density.

2. *Most Economical Voltage Drop.*

In order to obtain the most economical per cent voltage drop it is necessary to obtain Y as a function of the per cent voltage drop.

This is done as follows:

W = total load on secondary in watts.

V = voltage drop on secondary in per cent of delivered voltage.

B = constant relation between per cent voltage drop and the per cent power loss.

$$\text{Then } W = L_D S = \frac{A E^2 V}{300\, B\, S}$$

$$\text{Whence } S = \frac{E}{17.32}\sqrt{\frac{A V}{B L_D}}$$

Substituting this value for S in equation 4,

$$\text{Then } Y = \frac{1000\, K_1}{\dfrac{E}{17.32}\sqrt{\dfrac{A V}{B L_D}}} + K_2 L_D + \frac{g_L}{100}(3000\, w\, C_{cu} + C_{sr}) + \frac{E^2}{(17.32)^2}\,\frac{A V}{B L_D}\left[60.83\,\frac{L_D^2\, \rho\, t\, C_{e2}}{A\, E^2 \cos^2\theta}\right]$$

$$= 17{,}320 \frac{K_1}{E} \sqrt{\frac{B L_D}{A}}\, V^{-1/2}$$

$$+ 0.2028 \frac{\rho\, t\, C_{e2}\, L_D}{B \operatorname{Cos}^2 \theta} V + K_2 L_D$$

$$+ \frac{g_L}{100} (3000 \times C_{cu} + C_{sr}) \tag{5}$$

The most economical per cent voltage drop is obtained when the first derivative of Y with respect to V equals 0.

$$\frac{d\,Y}{d\,V} = 0$$

$$= -1/2 \times 17320 \left(K_1 \sqrt{\frac{B L_D}{A}} \right) V_{ec}^{-3/2}$$

$$+ 0.2028 \frac{\rho\, t\, C_{e2}\, L_D}{B \operatorname{Cos}^2 \theta} = 0$$

Solving for V_{ec}

$$V_{ec} = 1223 \left[\frac{\operatorname{Cos}^2 \theta}{E\, \rho\, t\, C_{e2}} \right] \frac{B\, K_1^{2/3}}{A^{1/3}\, L_D^{1/3}} \tag{6}$$

Equation (6) gives the most economical per cent voltage drop as a function of the load density. For fixed values of the constants this equation may be plotted as shown on curve No. 4.

3. *Most Economical Transformer Spacing.*

In order to obtain the most economical spacing of transformers it is necessary to have Y as a function of S. This is obtained from equation (4).

$$Y = \frac{1000\, K_1}{S} + K_2 L_D + \frac{g_L}{100} (3000\, w\, C_{cu} + C_{sr})$$

$$+ S^2 \left(60.83 \frac{L_D^2\, \rho\, t\, C_{e2}}{A\, E^2 \operatorname{Cos}^2 \theta} \right)$$

The most economical spacing is obtained when the first derivative of V with respect to S equals 0.

$$\frac{d\,Y}{d\,S} = 0$$

$$= -\frac{1000\, K_1}{S_{ec}^2} + 2 \times 60.83 \frac{L_D^2\, \rho\, t\, C_{e2}}{A\, E^2 \operatorname{Cos}^2 \theta} S_{ec} = 0$$

Solving for S_{ec}

$$S_{ec} = 2.02 \left[\frac{K_1 E^2 \operatorname{Cos}^2 \theta}{\rho\, t\, C_{e2}} \right]^{1/3} \frac{A^{1/3}}{L_D^{2/3}} \tag{7}$$

Equation (7) gives the most economical spacing of transformers as a function of the load density.

It is necessary to limit the range of application of equation (7) to conditions where the voltage drop is less than 3 per cent. A second equation must be developed for 3 per cent drop to apply where the most economical drop would be greater than 3 per cent. Practical considerations limit the drop to that value.

From above

$$S = E \sqrt{\frac{A\, V}{300\, B\, L_D}}$$

Using $V = 3$ per cent

$$S = \frac{E}{10} \sqrt{\frac{A}{B L_D}} \tag{8}$$

= transformer spacing for 3 per cent drop.

Then, summarizing,

$$S_{ec} = 2.02 \left[\frac{K_1 E^2 \operatorname{Cos}^2 \theta}{\rho\, t\, C_{e2}} \right]^{\frac{1}{3}} \frac{A^{\frac{1}{3}}}{L_D^{\frac{2}{3}}}$$

$$< \frac{E}{10} \sqrt{\frac{A}{B L_D}} \tag{7a}$$

which is general for all cases. (See curve No. 5.)

4. *Most Economical Transformer Size.*

The most economical size of transformer will follow directly from equation (7a) since it would be that size which would just carry the load at the most economical spacing.

or,

$$T_{ec} = \frac{L_D\, S_{ec}}{1000} \tag{9}$$

(See curve No. 6.)

5. *Most Economical Wire Size.*

The most economical cross-section of wire is the cross-section which will give the minimum total annual cost with any particular type of transformer installation. Here, the condition of most economical spacing and size of transformers will be assumed.

Thus, substituting the value S_{ec} (equation 7) for S in equation 4,

$$Y = \frac{1000\, K_1}{2.02 \left(\frac{K_1 E^2 \operatorname{Cos}^2 \theta}{\rho\, t\, C_{e2}} \right)^{\frac{1}{3}} \frac{A^{\frac{1}{3}}}{L_D^{\frac{2}{3}}}}$$

$$+ K_2 L_D + \frac{g_L}{100} (3000\, w\, C_{cu} + C_{sr})$$

$$+ 60.83 \frac{L_D^2\, {}_m\, t\, C_{e2}}{A\, E^2 \operatorname{Cos}\theta^2} \left[2.02^2 \left(\frac{K_1 E^2 \operatorname{Cos}^2 \theta}{\rho\, t\, C_{e2}} \right)^{\frac{2}{3}} \frac{A^{2/3}}{L_D^{4/3}} \right]$$

It is possible to express w as a function of A as follows:

$$w = \frac{K_3 + K_4 A}{100}$$

Where K_3 and K_4 are found by plotting the weight of installed wire against its cross-sectional area. (See curve No. 2.)

The equation for annual costs per 1000 ft. now becomes

$$Y = \frac{496\, (K_1^2\, \rho\, t\, C_{e2})^{1/3}\, L_D^{2/3}}{(E^2 \operatorname{Cos}^2 \theta)^{1/3}} A^{-1/3} + K_2 L_D$$

$$+ \frac{g_L}{100} [30\, (K_3 + K_4 A)\, C_{cu} + C_{sr}]$$

$$+ 248.5 \frac{(K_1^2 \rho t C_{e2})^{1/3}}{(E^2 \operatorname{Cos}^2 \theta)^{1/3}} L_D^{1/3} A^{-1/3}$$

Simplifying

$$Y = 744.5 \left(\frac{K_1^2 \rho t C_{e2}}{(E^2 \operatorname{Cos}^2 \theta)} \right)^{\frac{1}{3}} L_D^{1/3} A^{-1/3} + K_2 L_D$$

$$+ \frac{g_L}{100} [30 (K_3 + K_4 A) C_{cu} + C_{sr}] \quad \textbf{(10)}$$

Equation (**10**) gives the annual cost per 1000 ft. of line, using the most economical spacing of transformers.

The most economical cross-section of wire is obtained when the first derivative of Y with respect to A equals 0 or

$$\frac{d Y}{d A} = 0$$

$$= - 1/3 \times 744.5 \left[\frac{K_1^2 \rho t C_{e2}}{E^2 \operatorname{Cos}^2 \theta} \right]^{\frac{1}{3}}$$

$$L_D^{1/3} A_{ec}^{-4/3} + \frac{g_L}{100} \times 30 K_4 C_{cu}$$

Solving for A_{ec}

$$A_{ec} = \frac{154}{g_L K_4 C_{cu}^{3/4}} \left[\frac{K_1^2 \rho t C_{e2}}{E^2 \operatorname{Cos}^2 \theta} \right]^{\frac{1}{4}} L_D^{1/4} \quad \textbf{(11)}$$

Equation (**11**) gives the most economical cross-section of wire using the most economical spacing of transformers.

It is necessary to limit the application of equation (**11**) to less than 3 per cent voltage drop and develop the equation for most economical wire size *with* 3 per cent drop. This is done as follows:

From the equation (**8**), the spacing which will give a 3 per cent voltage drop is,

$$S = \frac{E}{10} \sqrt{\frac{A}{B L_D}}$$

B may be expressed as a function of A as follows,

$$B = K_5 + K_6 A$$

Where K_5 and K_6 are found by plotting B against the cross-sectional area, (see curve No. 3). Then:

$$S = \frac{E}{10} \sqrt{\frac{A}{(K_5 + K_6 A) L_D}}$$

Substituting the value of S in equation (**4**), the expression for annual costs per 1000 ft. of line—(the spacing being limited for a 3 per cent voltage drop) becomes

$$Y_{3\%} = \frac{1000 K_1}{\frac{E}{10} \sqrt{\frac{A}{(K_5 + K_6 A) L_D}}} + K_2 L_D$$

$$+ \frac{g_L}{100} [30 (K_3 + K_4 A) C_{cu} + C_{sr}]$$

$$+ 60.83 \frac{L_D^2 \rho t C_{e2}}{A E^2 \operatorname{Cos}^2 \theta}$$

$$\times \frac{E^2}{100} \frac{A}{(K_5 + K_6 A) L_D}$$

Simplifying

$$Y_{3\%} = \frac{10{,}000 K_1 L_D^{1/2}}{E} \left(\frac{K_5}{A} + K_6 \right)^{\frac{1}{2}}$$

$$+ K_2 L_D + \frac{g_L}{100} [30 (K_3 + K_4 A) C_{cu}$$

$$+ C_{sr}] + 0.6083 \frac{\rho t C_{e2} L_D}{\operatorname{Cos}^2 \theta (K_5 + K_6 A)} \quad \textbf{(12)}$$

Equation (**12**) gives annual cost per 1000 ft. of line using a spacing which limits the voltage drop to 3 per cent at full load.

The most economical cross-sectional area is obtained when the first derivative of $Y_{3\%}$ with respect to A is equal to 0.

$$\frac{d Y_{3\%}}{D A} = 0$$

$$= 1/2 \frac{10{,}000 K_1 L_D^{1/2}}{E} \left(\frac{K_5}{A_{ec}} + K_6 \right)^{-\frac{1}{2}}$$

$$\left(- \frac{K_5}{A^2_{ec}} \right) + \frac{g_L}{100} \times 30 K_4 C_{cu}$$

$$- 0.6083 \frac{\rho t C_{e2} L_D}{\operatorname{Cos}^2 \theta (K_5 + K_6 A_{ec})^2} K_5$$

From which

$$\frac{5000 K_1 K_5 L_D^{1/2}}{E \left(\frac{K_5}{A_{ec}} + K_6 \right)^{\frac{1}{2}} A^2_{ec}}$$

$$+ 0.6083 \frac{K_6 \rho t C_{e2} L_D}{\operatorname{Cos}^2 \theta (K_5 + K_6 A_{ec})^2}$$

$$= 0.30 g_L K_4 C_{cu} \quad \textbf{(13)}$$

Equation (**13**) gives the most economical cross-sectional area of wire when the spacing is limited by a 3 per cent voltage drop. (See curve No. 7.)

B. Derivation of the Practical Curves

1. *Load Curves for Secondaries.*

From equation (**7a**)

$$S_{ec} = 2.02 \left(\frac{K_1 E^2 \operatorname{Cos}^2 \theta}{\rho t C_{e2}} \right)^{\frac{1}{3}} \frac{A^{1/3}}{L_D^{1/3}}$$

$$< \frac{E}{10} \sqrt{\frac{A}{B L_D}}$$

From the combination of these two formulas the load curves for secondaries were obtained.

The lines showing the various load densities are obtained as follows:

$$\text{Total load in kw.} = \frac{L_D}{1000} \times S_{ec} \qquad (17)$$

(See curve No. 10.)

2. *Line Cost Curves.*

From equation 3,

$$Y_L = \frac{g_L}{100}\,(3000\, w\, C_{cu} + C_{sr}) + 60.83\, \frac{L_D{}^2\, S^2\, \rho\, t\, C_{e2}}{A\, E^2 \operatorname{Cos}^2 \theta}$$

The line cost curves are obtained by substituting the actual values of the various constants into this equation. (See curve No. 11.)

3. *Transformer Cost Curves.*

Annual cost of the transformer =

$T_{T1} = g_T$ (Cost of transformer + cost of light . arrest . + cost of installation) + inspection
+ cost of core loss
+ cost of copper loss

$= \frac{g_T}{100}$ (Cost of transformer + cost of lightning arresters + cost of installation)
+ cost of inspection

$$+\, C_{e1} \times 365 \times 24 \times \frac{\text{core loss}}{1000}$$

$$+\, \frac{L_D{}^2\, S^2}{E^2 \operatorname{Cos}^2 \theta}\, R_T \times 365 \times t \times \frac{C_{e2}}{1000} \qquad (18)$$

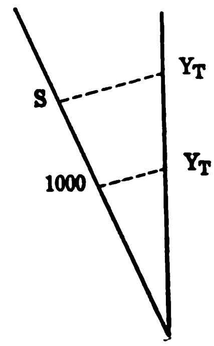
The method for determining Y_T (the cost per 1000 ft. of installation) graphically from Y_T (the total cost on one transformer) is as follows,

$$\frac{S}{1000} = \frac{Y_{T'}}{Y_T}$$

$$\therefore\; Y_T = Y_{T'} \times \frac{1000}{S}$$

($Y_{T'}$ = total annual cost on a transformer)
Y_T = annual cost of transformers per 1000 ft. of installation)
(See curve No. 12.)

Hence by adding the diagonal scale at the left, Y_T may be obtained from $Y_{T'}$, as follows by the method of similar triangles. Draw a line from the value of $Y_{T'}$, obtained on the vertical scale to the value of S used, on the diagonal scale. Draw a parallel line through 1000 ft. on the diagonal scale and where it intersects the vertical scale will be found the desired value of Y_T.



CORRESPONDENCE

THE ICE PROBLEM

To the Editor:

On page 786 of the JOURNAL for August 1920, there is an article entitled "An American Hydraulic Laboratory," which is of unusual interest to me.

For many years, almost single-handedly, I have been demonstrating the fact that submerged hydraulic apparatus—insulated or protected from the cooling action of the winter atmosphere—can easily be made immune from frazil, or anchor ice, attacks. The small amount of energy, in the form of heat, which is needed to secure such immunity makes the undertaking attractive to those who are impressed with the necessity of uninterrupted service from hydraulic plants.

During the past couple of years, I have, I think, taken a long step forward and have been showing with the aid of "moving" and other pictures that ice, itself, can be easily and economically *prevented from forming* in a stream or lake.

It appears to me that Ice-Prevention is on a par with Fire-Prevention, and that the very small amount of heat required to prevent ice from forming is quite comparable with the small amount of moisture which will often *prevent* inflammable materials from catching fire. Immense quantities of water are needed to stem the onrush of a conflagration—or to confine it to the limits of its starting point—but a few drops of water might in the beginning have quenched the spark which started the conflagration.

Crystallization is stayed or delayed in water at the critical temperature until an ice-forming nucleus is introduced, or until one is created by agitation; then crystallization proceeds with great rapidity—each new particle of ice becoming, in turn, the nucleus for the creation of myriads of others. The sequences of procedure in ice-formation resemble, greatly, the cumulative activity of a conflagration.

And so, also, it seems to be with ice. A "little" heat —(like the "little" moisture for fire-prevention)—applied to the molecule of water about to crystallize *prevents* its crystallization and stays the starting of the "conflagration" of ice.

The above points have already been presented to a number of technical gatherings and will, it is hoped, be again submitted, with illustrations, to some Sections of the Institute during the approaching meetings season. But it would give me much pleasure to present the material which I have gathered during many years to some "competent experimenters" in a "Hydraulic Laboratory" if the latter were equipped with the means of further widening the trail which I have been blazing.

These hydraulic and ice problems are, in my opinion, of nation-wide interest.

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The Measurement of Maximum Demand

AND

The Determination of Load Factor

BY PERRY A. BORDEN

Hydroelectric Power Commission of Ontario.

SINCE Hopkinson in 1892 first suggested the idea that the distribution of a customer's load throughout the day should have some bearing upon the amount which that customer should pay to the Central Station for his power, the subject of demand and load-factor measurement in its various aspects has been many times discussed. In the determinination of watts, amperes or any similar electrical quantity we have definite units upon which to base our measurements, and there is little room for controversy. But, when the quantity "demand", being a more or less mathematical concept, embodying the combination of electrical units with time in a rather indefinite way, comes under consideration, very divergent views as to its nature, measurement and true significance may be and have been expressed.

The object of the present paper is not to introduce any radically new ideas, nor is it to advocate any particular policy as a panacea for all difficulties which beset the rate maker in his work. It is rather to give a bird's-eye view of the situation as it exists today; and, in an endeavor to reconcile some of the different opinions on the subject to show an actual comparison of the performances of a number of demand-measuring devices. And from this comparison have been deduced some interesting facts which would seem to have an important bearing upon the present day status of industrial load measurement.

For the purpose of a systematic study of the measurement of electrical demands the subject may be divided into three natural sections as follows:

I. The electrical quantity upon which the measurement is performed.

II. The method by which the measurement is accomplished.

III. The results obtained by the several methods upon a variety of types of loads.

Although these aspects of the subject are closely related, they will be considered as independently as possible, one of another.

I. The Quantity Measured

In the establishment of a scale of charges for electrical energy the rate-maker at once recognizes the fact that he has the choice of a number of electrical quantities upon which to base his calculations. These quantities are affected in various ways by the nature and magnitude of the load under consideration. If the value received by a consumer from a certain amount of electricity were in direct proportion to the expense incurred in placing that electricity at his disposal, the problem of establishing charges for electrical power would be immensely simplified. Unfortunately, however, such is not the case; and the problem becomes one of finding a middle way between an absolute flat rate, based only upon the installed capacity of the load, and a straight energy charge established upon the readings of a watt-hour meter.

In hydroelectric power plants, where the fuel costs are nil, and the apparatus may be run at its ultimate capacity at practically no more outlay than at very light loads, the limitation of output is the *capacity of the equipment.* In fuel-consuming plants, where the combustion of coal or of oil is the source of energy, the cost of fuel, (the only item of cost whose value bears any direct ratio to the energy output), is seldom over half the annual expense of the undertaking, the remaining charges being practically dependent upon the capacity of the plant. In either case, therefore, the relationship between the watt-hours supplied and the cost of operation is a very indefinite one. The main object to be attained is that of keeping up the load factor; and the logical way to produce this result is to encourage each customer to do his share. It has of course, been demonstrated that cases may exist where it is desirable to have on the system a customer with a low load factor, who, by placing his peaks at the discretion of the Central Station, may serve to fill up the valleys in the load curve caused by another customer who cannot so well control his demands; but practically all such cases are of a particular nature; and as such, need not be considered under the general head. The most natural way to encourage a high load factor is by the production of a direct reaction upon the customer's pocketbook, and hence the justification of the use of demand in the establishment of rates.

The "capacity of the equipment" referred to in the former paragraph is a term which in itself might furnish material for much discussion, and its very uncertainty adds much to the intricacies of the problem of demand measurement. To the mechanical engineer such a term would present little difficulty, as it would merely signify a power value beyond which the weakest link in the system would fail. But to the electrical engineer the matter of heating of equipment is usually fully as important as any purely mechanical feature; and this heating is not in direct propor-

To be presented at a meeting of the A. I. E. E., Philadelphia, October 8, 1920.

tion to the amount of energy delivered to the consumers.

The temperature rise of a piece of apparatus is governed by the relation of the energy losses therein to the facilities for dissipating the heat generated, and to the time allowed for the heat to distribute itself away from its source. All of these factors are subject to great variation. If then, we wish to base our charge upon the capacity of the plant or investment necessary to provide power for the customer in question, we must pay some consideration to the temperature rise of our equipment due to his load. This means that, to obtain a fair basis we should endeavor to determine the energy loss produced in our equipment by the load under consideration and to incorporate this value in his power bills.

The direct measurement of loss, while possible on a single unit by use of a differential wattmeter, or by other means, is not practicable where the one bus supplies a number of independent loads. It is desirable, therefore to install upon each circuit that type of measuring instrument whose indications bear the closest relationship to the enrgy losses in the supply system. Hence the question, "What electrical quantity shall we measure?"

As possible answers to this question, consideration is given to the follwing quantities:

(a) Watts ($E\ I$ Cos ϕ)

The majority of the present day demand meters operate as wattmeters and give the maximum demand of the load in watts consumed. This method has the advantage that it is universally applicable to all classes of loads,—direct and alternating, single-phase and polyphase, balanced and unbalanced. This value while representing the demands made upon the mechanical portions of the system, is not of necessity proportional to the heating effects.

(b) Volt-Amperes ($E\ I$)

Since for a given energy load, the heating of equipment is manifestly greater at low power factors than at high, a consideration of volt-amperes without regard to the actual energy supplied will have a tendency to encourage operation at high power factor, and thus reduce energy losses. This method is already used to a considerable extent by the employment of a watt-demand meter whose readings are coupled with those of a power factor meter at the time of the maximum demand. This scheme, however, or the use of a reactive-volt-ampere-meter in conjunction with a watt-demand meter involves the use of two instruments, one at least, of the curve-drawing variety; and is, therefor, suitable only for comparatively large loads from which the revenue would be sufficient to justify the expense of the equipment.

The volt-ampere meter has not yet been developed in a form suitable for direct determination of maximum demand, and does not at this time appear capable of such development, at a price to compete with the watt-demand meter on ordinary commercial measurements.

(c) Amperes (I)

The earliest types of demand indicators were dependent for their indications upon current alone. And, since it is the current which is responsible for the heating of conductors, there would seem to be justification for their use. On polyphase circuits, however, they are likely to introduce confusion and uncertainty.

(d) Amperes Squared (I^2)

As the heating of a conductor is directly proportional to the square of the current flowing, it would seem that an instrument measuring demand upon this basis would find a certain sphere of usefulness. Such a meter would be identical in its principles with an ampere-demand meter, but would have an inherently uniform scale. Its construction, to operate upon either a thermal or an electro-mechanical principle should be quite practicable. It would, however, on unbalanced loads, be subject to the same limitations as the ampere-demand meter.

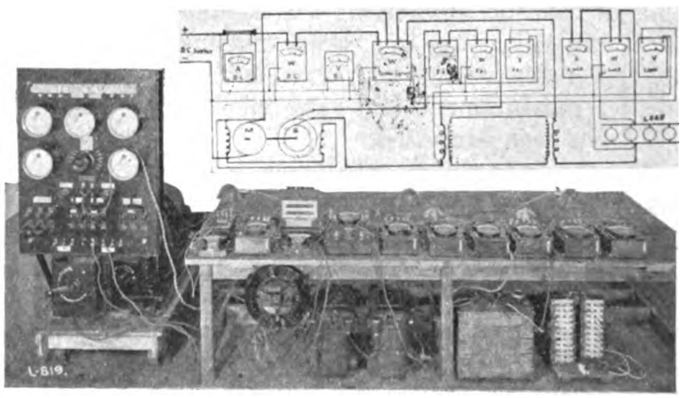

FIG. 1—TEST ON TRANSMISSION LOSSES

(e) Actual Energy Losses ($K\ E^m + R\ I^n$)

As stated above, while it is possible to measure the actual energy losses in a simple system, where but one load is fed from the portion of the plant under consideration; it is not practicable, when several loads are fed from one source, to apportion the responsibility for the energy losses without the most intricate mathematical operations and complicated metering equipment. The accurate measurement of energy losses under ordinary working conditions may be looked upon as a matter of purely academic interest and here laid aside in favor of some more practical if less precise method.

As a matter of interest, a number of tests were made upon a load fed through a series of circuits forming an artificial transmission system. The arrangement, as shown in Fig. 1, consisted of a direct-current motor driving a small alternator whose output was stepped up to the line, and down again to the load. Complete measuring equipment was installed at several points along the system, and a differential wattmeter connected in so as to totalize the losses. One set of curves was made with non-inductive load-

ing, and another considerable reactance in the circuit to produce a low power factor.

The values obtained in these tests are shown in Figs. 2 and 3 where the various quantities are expressed as curves on a base of watts input to the system. The curve of total loss in the system manifestly represents only the difference between the total input and the total output, and the same, of course, holds good for any portion of the system which it

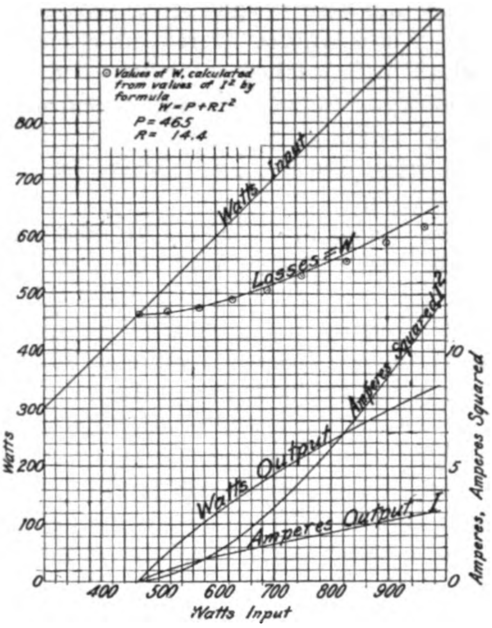

Fig. 2—Loss Measurements on Unity Power-Factor Load

is desired to investigate. The total losses of the system, including those of the motor-generator set, the transformers and the line, are in this case taken, as being representative of the greatest variety and magnitude of energy losses, and therefore approaching most closely the average power system.

A glance at the curve sheets suffices to show that, whereas the watt and volt-ampere curves bear but little resemblance to that of the energy loss; a strong similarity exists between the loss curve and the curve of amperes squared. It is a simple matter to develop an expression connecting the two quantities, which, from the values of amperes squared will enable us to construct the curve of losses.[1] This, while quite applicable to those portions of the system which supply only one customer, is subject to the same handicap as other methods of total energy loss determination, where several consumers are fed from the one bus.

Summary—Part I.

1. A fair and equitable charge for electrical energy cannot be made on a basis of energy consumption alone. Some consideration must be made of the customers' demand upon the capacity of the plant.

2. In the determination of demand, cognizance should be taken of the heat produced in the equipment by the load under consideration, as well as of the mechanical limitations of the plant.

3. While the mechanical limitations of the plant bear a direct relationship to the energy output, the heating limitations are in direct proportion to the energy losses in the electrical equipment.

4. Energy losses cannot generally be measured, and are usually very difficult to estimate accurately.

5. Energy loss may be expressed as the sum of a function of the voltage and a function of the current; and considering the complicated nature of the expression necessary to give a precise representation of this value, the voltage may usually be considered as constant, and the loss said, with little sacrifice of accuracy, to vary as the square of the current,

6. An exact apportionment of the I^2R losses among several loads fed from one system is made difficult by the fact that, while the total loss varies as the square of the total current, the ratio of the losses due to the respective currents is an indefinite quantity, depending upon a number of variables whose values it is not practicable to obtain.

7. Since the true basis for demand measurement is an exceedingly evasive quantity, not capable of determination under practical working conditions, it is necessary that some compromise be made, and

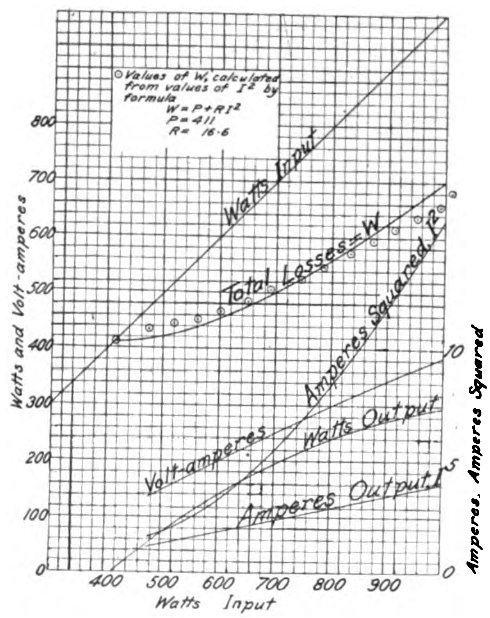

Fig. 3—Loss Measurements on Low Power-Factor Load

the nature of this compromise must be subject to local conditions and to personal opinions on the economic questions concerned.

8. Tests would seem to indicate that, though volt-amperes cannot be said to be an exact representation of the quantity upon which demand would be based, they furnish us with a definite quantity whose value approaches nearest to the desired approximation.

1. See Appendix No. 1.

II. The Method of Measurement

In the present state of the art, there are recognized several methods of determining demand: These include measurements from the charts of graphic recording instruments, and readings obtained from specially designed demand meters. While from an analysis of the graphic meter chart it should be theoretically possible to determine the average power for any period and to select the greatest of these averages as the maximum demand, any person who has tried to do this with the chart of a load having any considerable degree of variation realizes that a positive determination of the true average over a chosen period is seldom practicable.

The only workable method of measuring maximum demand from graphic meter charts is by selecting that portion of the curve during which the indication remains at its highest value for the duration of the required time period. This is known as the "Sustained Peak." While the use of this quantity, in that it cannot exceed the true maximum integrated demand, might well meet with the customers' approval, it may be very unfair to the Central Station, in that the value obtained cannot be higher than the minimum point of any depression which may occur during the period of maximum demand. Moreover, the depth of any instantaneous minima of the load curve as drawn by the graphic instrument will depend greatly upon the amount by which the meter movement is damped. In Fig. 4 is shown a reproduction of charts taken simultaneously on the one load, by curve-drawing meters of different types. One of these instruments was of the well-known relay type; while the other, operating upon the induction principle, had almost critical damping. From these charts it will be seen that, by a slight difference in the operating characteristics of the recording meters, the load is shown, not only as having sustained peaks of differing values,

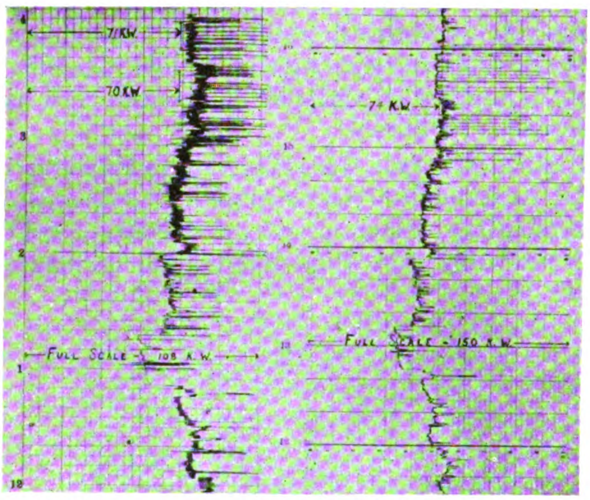

Fig. 4—Simultaneous Charts From Different Types of Curve-Drawing Meters Showing Sustained Peaks

but as having its peaks at different times of the day. Thus, on a fluctuating load, the values of maximum demand, as determined from the sustained peak are of little significance.

Since the ordinary curve-drawing meter does not justify its use for the determination of demand, it becomes necessary to investigate the possibilities of the various types of demand meters which, from time to time, have been developed; and to examine their principles of operation.

Among the numerous types of demand instruments now known to engineers there are recognized two groups, which are classified according to the principle of operation rather than the quantity measured. These classes are as follows:

1. Those from which an integrated value of the load is obtained.
2. Devices which are time-lagged and cannot, in the ordinary sense of the word, be said to give an integrated value.

Integrated Demand Instruments. The quantity determined by this class is usually the ratio of the total integrated value of the load consumed in the time interval to the time of the interval. This class naturally falls into five subdivisions of which, as we proceed, I shall endeavor to briefly describe one or more types to be found in each.

(a) Curve-drawing meters include all meters which give a continuous line record or chart of the quantity measured. From the charts so obtained it is possible by measurement or by integration to gain very complete information as to the load, its peaks, its total value and its demand over any desired period. But as shown in a previous paragraph, the systematic use of such instruments for the accurate measurement of demand is seldom practicable.

(b) Instruments which graphically record the demand for each successive time interval as fixed by a clock or other timing device, time also being recorded. The demand in each clock interval, and therefore the maximum demand, can be obtained from the record. This type and those in the two following classes operate upon what is known as the "Merz" principle, and are subject to the disadvantage that, the time periods being selected by a clock, no cognizance is taken of load conditions immediately previous or subsequent to each individual demand. The clock being unable to select the period of maximum power, the maximum demand as obtained from such an instrument is only the greatest of those demands which were measured by the individual meter in question. Two similar meters installed upon the same load, unless the tripping mechanisms operate in synchronism, need not indicate the same value. As examples of meters in this class may be named the General Electric type *G* meter, the Westinghouse type *R A* and the Piek or the N. E. I. C. meter.

The General Electric type *G* meter has essentially

two parts, a registering element and a timing element, both of which are mounted within the same case. In addition to the device proper, a complete outfit includes a contact device consisting of cam and contact brushes for mounting in the register of the watt-hour meter with which the demand meter is to be used. The registering element consists of a marking stylus, the electromagnet, ratchet and pawl mechanism, and gearing to transmit motion from the armature of the electromagnet to the stylus. The timing element consists of an eight day clock which drives the chart, and, at the end of each time interval, resets the stylus to its zero position. The charts are circular and arranged to cover a period of one week. They are made of a special coated paper similar to that used for steam engine indicator cards; and the record is made by a steel stylus.

The Westinghouse type *R. A.* meter combines the demand mechanism and the integrating mechanism in one case and the connection between the two is mechanical. The record paper is in the form of a strip and is of sufficient length to last for thirty-six days. The chart does not travel continuously but is advanced a short distance just before the pen is released and reset. Thus each demand indication is given a square top that makes it distinctly readable.

The Piek demand meter is probably the first graphic demand meter to make its appearance in this country. It was introduced about 1910. The measurement of energy is accomplished by a Westinghouse type *C* watt-hour meter bearing the ordinary integrating dial. Geared to, and operated by the meter is a parallel motion carrying a pen or stylus which travels in a straight line across the scale. The position of the pen is at all times recorded upon a paper chart driven forward by a self-winding clock. This clock serves also to drive a cam which, operating an electric tripping device, periodically releases the pen, and resets the demand mechanism to zero. These meters are built for periods ranging from one minute upwards.

(c) Instruments which, at the expiration of each time period, make upon a tape or chart; a record of the reading or of the advance of an integrating meter. These meters are very similar to the foregoing class, except that whereas in the former, the record is graphic, in this case it is in figures. The "Printometer," now known as the General Electric type *P* demand meter is the best known example. The instrument contains a set of cyclometer type-wheels which are electrically interlocked with the register of a watt-hour meter. They are moved forward at a rate representative of the flow of power through the meter; and will, therefore, at any instant give an indication which is equivalent to the reading of the dial. Through the agency of a rubber platen and a copying ribbon, this reading is printed on a paper tape. The outfit is not self-contained, the demand indicator being separate from the clock and the meter, and requiring, like the type *G*, a contact-making device to be fitted to the register of the meter.

(d) Instruments which indicate, but do not record the maximum demand, the time intervals being fixed by a clock or other timing device. In meters of this class, the reading is obtained from a pointer, which must be manually reset to zero, and which gives only the maximum demand since the last previous resetting. As examples of this class may be named the General Electric type *M* (formerly the Maxicator) and the Siemens demand meter.

In its general principles the type *M* is similar to the type *G*. As the stylus is replaced by a pointer, however, it is not automatically returned to zero. The mechanism which forces the pointer across the scale returns periodically to zero but the pointer remains at a maximum deflection, and is reset by hand when the meter reading is taken. Instead of a clock, the *M* 4, for alternating currents, has for a timing element a constant-speed motor similar in its construction and operation to the moving element of an ordinary watt-hour meter.

The Siemens meter consists of a demand attachment mounted in the same case with a watt-hour meter of the standard type. The clock is a small, electrically-driven unit which, by means of a cam, mechanically actuates the tripping mechanism. A driving dog periodically geared to the watt-hour mechanism, impels a pointer around a graduated scale, and the position of the pointer indicates the maximum deflection of the dog, and hence, the maximum demand, since the pointer was last reset. At the time of reading the meter, this pointer is manually reset to zero. The Siemens meter, being of the purely indicating type, requires no attention other than the periodic reading and setting of the demand pointer.

A considerable number of meters using the Merz principle have been developed by British and European manufacturers but these differ from the Siemens meter only in details of construction.

(e) Instruments which make a record on a tape or chart when a certain fixed and predetermined amount of energy has been consumed, time also being recorded. This class differs from class (c) in that the demand is shown for any time interval, irrespective of when the interval began and ended. In other words, when a predetermined amount of energy has been consumed, a record is made, while in class (c) instruments a record is made when the predetermined time interval has elapsed. It differs from class (a) in that the record is not a continuous one but periodic. Example: Ingalls demand recorder. In this meter the general scheme of operation is similar to that of the General Electric type *P* but the functions of the timing and recording elements are interchanged. A dot is made on the paper tape after the consumption of each predetermined block of energy. The rate of consumption is obviously greatest where the dots are most numerous.

Numerous attempts have been made to develop a meter which would overcome the selective characteristic of instruments of the Merz type; but owing to their mechanical complications, these cannot be said to have found sufficient favor to justify their production in quantities. A special instrument developed for this purpose by the writer is described in a later section of this paper.

Lagged Demand Instruments. A lagged demand instrument really comprises an indicating meter in which a retarding device is used, so that a definite time period must elapse before the full value is indicated. The time interval is independent of clock time.

The value measured by instruments in this general class differs from the integrated value by an amount which depends upon the particular type of instrument and the character of the load curve. With a perfectly steady load, all instruments of this class would indicate practically the same value as integrating instruments, but with a fluctuating load each type may give a different result. Hence, when referring to demands measured with instruments of this class, the particular type of meters employed should be mentioned. The class may be subdivided into the following two types:

(a) Instruments in which the rate of motion of the indicator over the scale is always proportional to the load. Example: Westinghouse type *R. O.* meter.

The Westinghouse type *R. O.* watt-hour demand meter, which made its appearance six years ago, embodies some distinctly original features. It combines in the one mechanism a wattmeter and watt-hour meter, both actuated by the same electromagnetic elements. The wattmeter is prevented from registering the instantaneous value of the load by an escapement operated from the watt-hour meter shaft. The indicating mechanism, therefore, constantly endeavors to indicate the load; but can only approach that value (as long as the indication is less than the load) at a rate proportional to the load. Since the speed of travel is proportional to the load, it will be seen that an indication of any sustained load will be attained at the end of a definite and constant time interval. The time period is thus established independently of any clock. Engaged with the indicating mechanism is a maximum pointer, which, by indicating the greatest deflection of the wattmeter element, determines the maximum demand.

Several instruments measuring substantially the same quantities as the *R. O.* meter have recently been patented, but as they have not made their appearance on the market it is not necessary to refer to them here.

(b) Instruments in which the rate of motion of the indicator decreases with the time of deflection. Examples: Wright, Reason, Lincoln type *R. H.*, General Electric types *W* and *H*.

The Wright meter is in principle a differential recording thermometer which measures the heat produced by an electric current. It consists of two bulbs of approximately the same size, connected by a U-tube filled with liquid and provided with a third tube; in close proximity to which the scale is fixed. The current is carried through a heating coil wound on one of the bulbs. The heat produced causes the air to expand and to depress the column of liquid in one side of the U-tube, causing it to rise in the other and overflow into the reading tube. The height to which it finally rises is an indication of the maximum value of the current which has passed through the coil.

The Reason demand meter is a similar piece of apparatus in which the glass tube is tilted by the measured current flowing in a solenoid, thus allowing the liquid to flow into the reading tube. Both this and the preceding type, being unaffected by the voltage of the circuit are purely ampere-demand meters.

The Lincoln type *R. H.* meter having already been described both in theory and in mechanical construction to the A. I. E. E.,[2] it is assumed that a very brief description will suffice to recall to mind its operating principles.

This demand indicator operates upon the principle of heat storage. By an ingenious, though simple arrangement of transformers and resistors it has been practicable to obtain a thermal quantity which is directly proportional to the energy in the circuit. An expanding spring, connected to a deflecting pointer enables an indication to be obtained of the watts passing through the metering element, and the instrument constitutes a true thermal wattmeter. The time element is introduced by loading the heaters with metallic masses, which do not instantly respond to temperature changes. Upon any change in load, the temperature of the mass begins to change and continues to do so until the rate of heat loss balances the rate at which energy is being supplied. This change in temperature takes place according to what is known as a logarithmic law.

The General Electric type W demand meter is essentially a polyphase watt-hour meter with both electrical elements acting upon one disk, and a very strong damping system acting on the other disk to produce the necessary time lag. The rotating element is opposed by a series of springs which permit the disks to make three complete revolutions while the pointer makes one revolution. The instrument thus becomes an indicating wattmeter, very much over damped. This meter is usually constructed to have a time period of five minutes.

The type *H* is a thermal instrument and records the maximum current. The instrument works on a differential thermometer principle. Two similar thermostatic springs are mounted on studs, their free ends being connected by a cord which passes over

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[2] Trans. A. I. E. E. Vol. XXXIV, p. 2297

a spindle, the latter carrying an arm which engages the pointer. The air temperature affects both springs to the same extent, thus causing no deflection of the pointer for its variations. In one of the two spring-supporting studs is contained a heating element through which the main current is passed; thus when current is being used, the temperature of one spring is raised above that of the other, causing the shaft to turn, and so produce a reading. This instrument combines in its principles the idea of the logarithmic increment of temperature, with that of the flow of heat along conductors.

The demand meters referred to above include only types which are now, or have been in actual commercial use. It is not the intention to convey the impression that these are all the types that have ever been de-

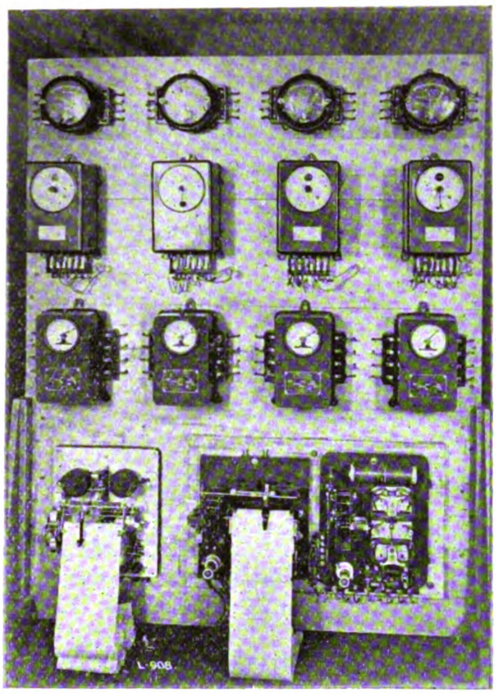


Fig. 5—Comparative Demand Meter Outfit

veloped. To obtain an adequate idea of the multitude of methods and principles which have been proposed for the measurement of this elusive quantity, it is necessary only to refer to the records of the Patent Offices for the past fifteen years.

A considerable number of "Excess Meters" have from time to time made their appearance but as these instruments cannot properly be considered as coming under the head of "Demand Meters," they are not given consideration in this paper.

III. Operation on Various Loads

Provided the laws governing the mechanical operation of any type of demand meter are known, it is possible to predetermine the indications of an instrument in which the quantity measured undergoes any prearranged cycle of variations. In comparisons of demand indicators this has frequently been done, and an opportunity thus given to study the inherent characteristics of various types of demand measuring devices, particularly at the start and the finish of the duty cycle.

Under actual service conditions, however, the duty cycle is seldom exactly duplicated; and as a slight change in this cycle might produce varying effects upon the operation of different instruments, the element of uncertainty so introduced would seem to justify service tests on actual typical loads as being the only fair comparison of demand meter types.

With the object of carrying out such tests, the writer collected a number of typical instruments, all of which were installed upon an easily portable panel, so arranged as to be cut in on the metering circuits of such typical installations as were accessible. This outfit is shown in Fig. 5, there being three distinct types of meters and, of each type, four time periods. The types are as follows: Top row, Lincoln thermal storage (logarithmic); second row, Siemens (Merz type, or block-interval); third row, Westinghouse type *R. O.* (mechanically lagged).

The time periods were 10, 20, 30 and 60 minutes for the two latter types, and 10, 15, 30 and 40 for the first, it being borne in mind that the time period of a logarithmic meter is arbitrarily defined as the time required for the instrument to reach ninety per cent of its ultimate indication on a steady load. Each meter was adjusted to its maximum possible accuracy and frequently checked during the progress of the tests. The 10-minute and 30-minute logarithmic meters were supplied by the manufacturer from standard stock parts; the other periods being made up from such material as was at hand. These latter, when tested, were found to have time periods of 15 and 40 minutes respectively; which values were adopted as satisfactory for the tests.

The block-interval meters being of a pre-war European type, it was not practicable to obtain suitable timing gearings; and special methods were used. Instead of cutting new gears for the timing elements, the clocks were removed, and replaced by small solenoids operated from a contactor carried by the master clock in the continuous recording meter.

The mechanically lagged meters were stock instruments, which were fitted with suitable timing gears specially ordered from the factory.

As it is a well-known fact that none of the types of meters commercially used will infallibly measure demand upon an arithmetical basis; and as it was very desirable to have some form of instrument which could be considered as a standard of comparison, it was found necessary to develop and construct a meter for this purpose. As this meter embodies some rather unique features which may be of interest, the following description of its working principles and operation is given.

The instrument itself was built of such odds and

ends as could be found among the accumulation upon the shelves of the meter shop; and, as may be readily seen by reference to the illustration, (Fig. 6), does not partake of the general appearance of the apparatus produced by any of the well-known manufacturers of electrical equipment. However, as this device was constructed solely for experimental purposes, the use of such a nondescript instrument may be pardoned on the grounds of the interesting and satisfactory results obtained.

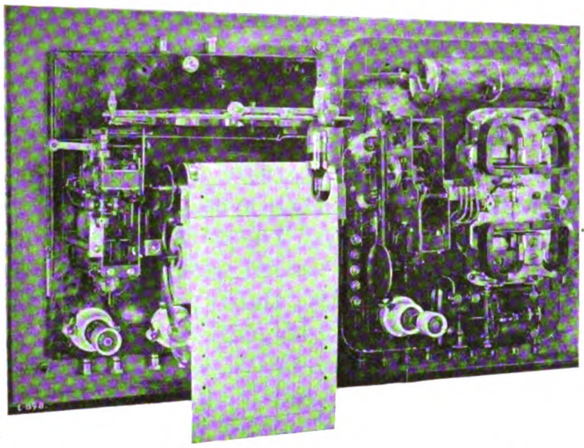


FIG. 6—CONTINUOUS RECORDING DEMAND METER

To give a clear understanding of the operation, a diagrammatic sketch is shown in Fig. 7. It will be observed that the working principle is exceedingly simple. A paper chart is caused to advance at a speed proportional to the load on the circuit, while a pen is propelled across the paper at a constant velocity in a direction perpendicular to the travel of the chart. The first motion is accomplished by means of a watt-hour meter, controlling the speed of the

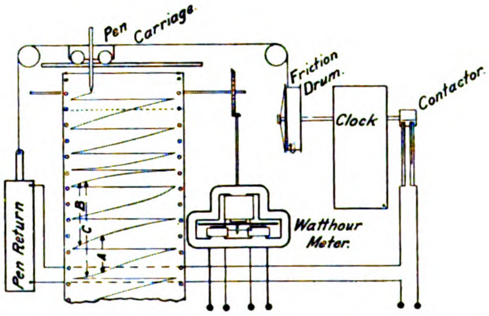


FIG. 7—DIAGRAM OF CONTINUOUS RECORDING DEMAND METER

paper travel; while the second motion is produced by a clock, winding a cord about a friction-driven drum, so that the pen makes its transit of the paper in exactly ten minutes. At the end of each ten-minute period, a contactor driven by the clock energizes an electrical device, which forcibly returns the pen to its zero position, the cord unwinding from its drum, which slips on the arbor of the clock.

As the return of the pen is practically instantaneous it will be seen that the chart takes the nature of a series of curves one above the other, the corresponding ordinates on successive curves being separated by intervals of ten minutes. It will be seen that the slope of any of the curves at any instant is proportional to the load at that instant; and the series of curves may be considered as the translated portions of one continuous curve whose height from the point of starting represents the integrated value of the load.

Since measurement along any ordinate represents the advance of the paper, *i. e.* the integrated load, during the time period between two crossings of that ordinate by the pen, it manifestly represents the average load or demand during that period. It only remains, then, for the measurement of maximum ten-minute demand, to select the ordinate whose length between two successive curves is greatest and to express its length in terms of the units measured by the integrating meter.

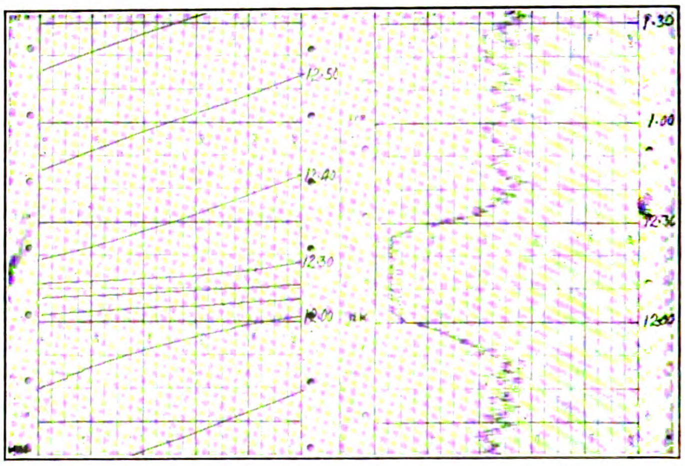


FIG. 8—SIMULTANEOUS CHARTS FROM CONTINUOUS RECORDING DEMAND METER AND CURVE-DRAWING WATTMETER

Similarly, demands for twice the normal time period of the meter may be scaled off by measuring the distance along the greatest ordinate between alternate curves; and for greater multiples of the normal period, by selecting the desired number of curves to be spanned. Thus, from the one chart it is possible to determine, not only the true maximum demand for the fundamental period, but the demand for any multiple of that period.

Referring to the chart shown in Fig. 7, the maximum ten-minute demand is indicated by the distance A, the twenty-minute demand by $B/2$ and the thirty-minute by $C/3$.

Fig. 8 shows a portion of chart from this instrument, side by side with the simultaneous record of a graphic wattmeter upon the same load. These curves illustrate the operation of the demand meter at the time of the noon valley on an actual factory load.

The portable panel carrying the demand meters and a curve-drawing wattmeter, was wired up to the metering circuits of several types of load, and careful

records were taken of the indications. These records were averaged for each meter over several days, and the averaged readings expressed in the form of curves, as shown in Figs. 9 to 14.

Since demand is one of the elements entering into the computation of load factor, and since the values of demand may vary widely, according to the method

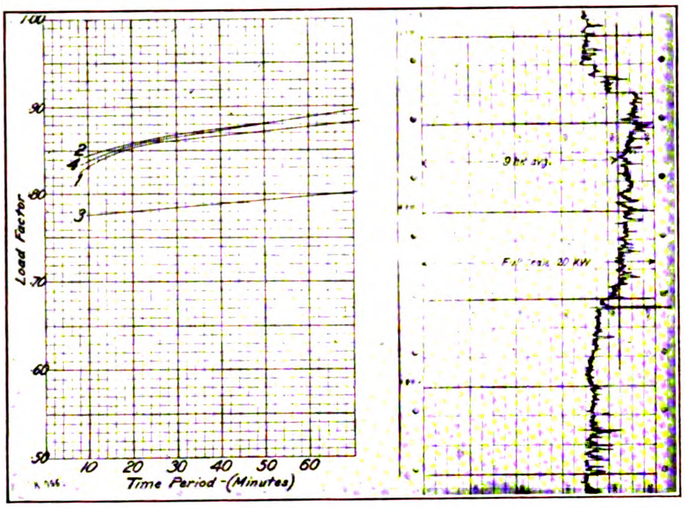


Fig. 9—Load of Electrical Testing Laboratory

of determination, it must necessarily follow that the value of load factor is subject to the same wide variations. But the latter quantity, being a ratio, and independent of the magnitude of the load, may be used in comparisons with much greater felicity than may the actual values of demand. The curves, therefore, are expressed in terms of load factor plotted

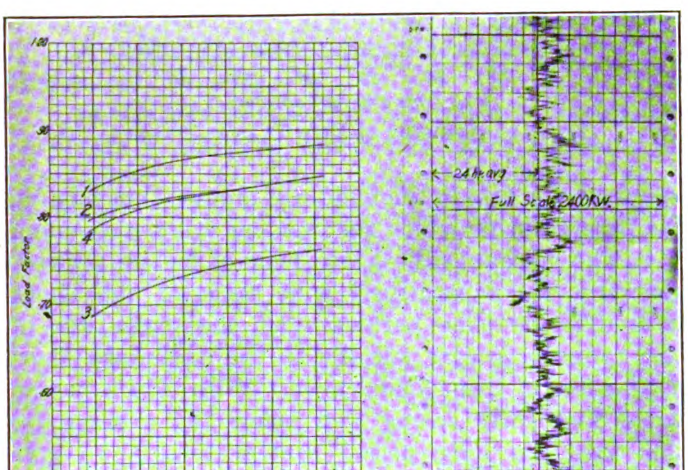


Fig. 10—Load of Rubber Manufacturing Plant

against time period, a separate curve for each type of meter and a separate set of curves for each class of load. The numbering of the curves is the same as the vertical arrangement of the meters on the panel, *viz.*—1, logarithmic; 2, block-interval; 3, mechanically lagged; 4, true arithmetical average. With each set of curves is shown a sample of graphic wattmeter chart from the same load. In the load factor calculations, the average power for the day is taken as the average over only that time during which the load curve maintained its peculiar characteristic nature.

Fig. 9 shows the values obtained with the meters installed upon the total load of an electrical testing laboratory. In this case the load was fairly steady all day, the peak occurring late in the afternoon, due to the additional power required by the lighting circuits.

Fig. 10 illustrates the curves obtained from the load of a large rubber manufacturing plant. This was a continuous 24-hour load with a deep noon valley. The peak, which was only slightly in excess of the average, usually occurred late in the afternoon.

The curves in Fig. 11 were obtained upon the feeder to a small machine shop, whose load included two

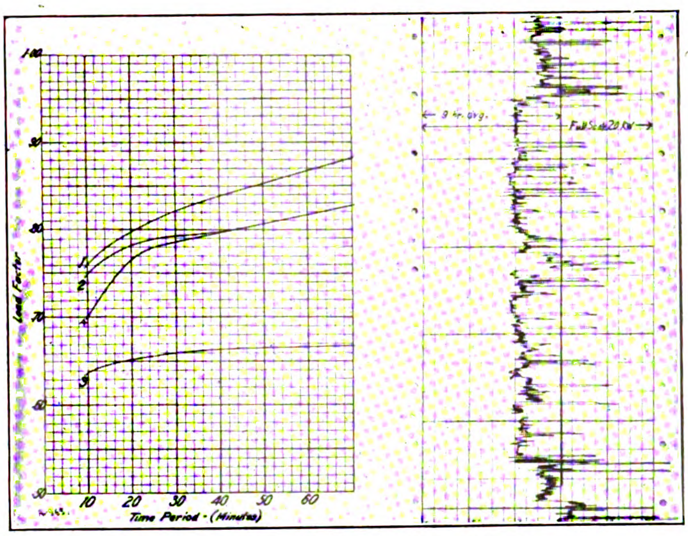


Fig. 11—Load of Smll Machine Shop

heavy freight elevators. These are responsible for the severe swings above the days average. This load is included in the load referred to in Fig. 9.

In Fig. 12, are seen the results obtained with the load of a heavy brass-rolling mill. Here are found numerous and heavy swings both above and below the average for the day.

Fig. 13 shows the curves from a city tramway load; the section investigated operating from fifteen to twenty cars. The load curve shows, even during the hours of peak load, frequent depressions approaching the zero value.

The curves illustrated in Fig. 14, are presented more as a matter of interest than for any real technical value. They are plotted from values obtained by averaging the data upon which the other five sets of curves were based. It will be observed that the several curves lie in closer proximity to one another than in any of the individual tests.

It will readily be understood that these investigations might have been carried out indefinitely upon a

great variety of typical load curves; but the results obtained on the five loads which were examined, indicate that a particular case must be made of almost every installation, and that attempts to generalize or to classify would be productive of little valuable information. Owing to the diverse nature of the results of the several tests, such facts as could be considered typical of the load curves or of the meter types can be presented only in a more or less disconnected way; and, as such, appear in the following summary.

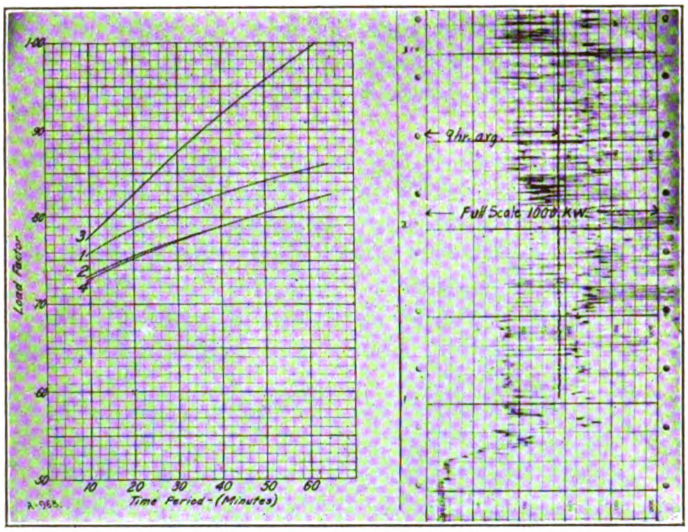


Fig. 12—Load of Brass Rolling Mill

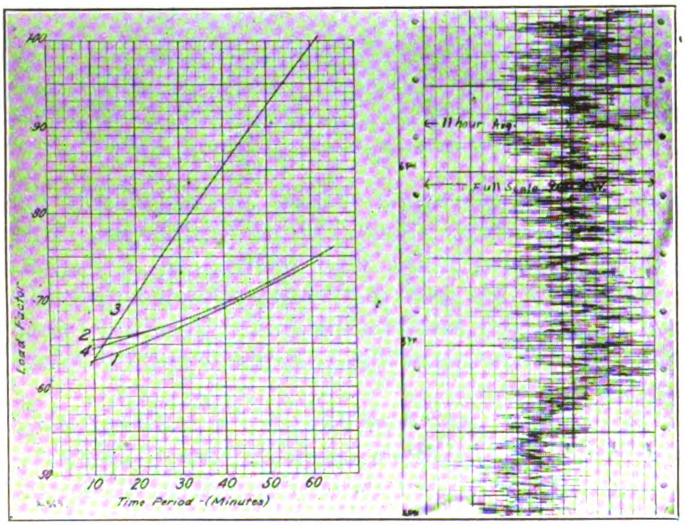


Fig. 13—City Tramway Load

Summary—Part III.

1. Except upon the most fluctuating loads, the demand meters of one type, and of differing time periods gave indications which, generally, within the limits of accuracy of the individual instruments, were in close agreement with one another.

2. The load factors as determined from day to day upon the one connected load, by a meter of one time period, differed more widely than did the values determined by the several meters of that type, upon one day's run.

3. The values of load factor as determined from readings of meters of the Merz, (or block-interval) type were found to be very erratic; and even when averaged for the one load over several days, very difficult to reconcile into a smooth curve. A higher value of load factor (*i. e.* a lower peak) was usually shown for the short periods, coming into approximate agreement with the true value of the arithmetical average, as determined by the continuous recording meter, as the time periods became longer. This phenomenon is doubtless due to the frequency with which these meters would trip in the middle of a peak, thus missing the period during which the demand was a maximum.

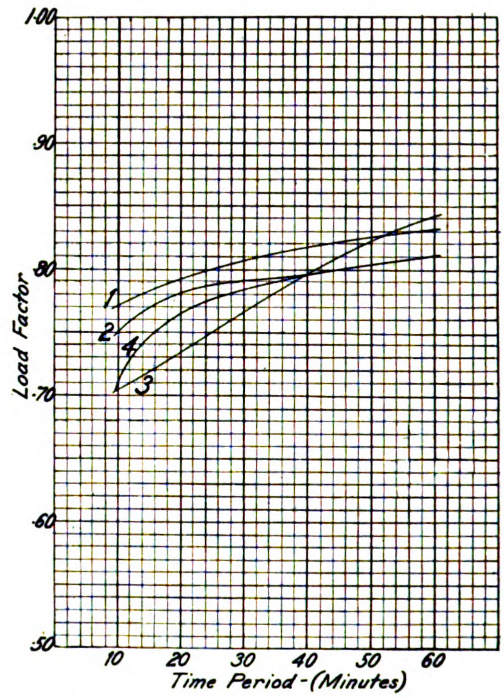


Fig. 14—Average of Five Typical Loads

4. The mechanically lagged type of meters showed, generally, a comparatively wide range of indications with differing time periods; but the magnitude of this range was very subject to the secondary characteristics of the load curve. With loads whose value frequently swung well below the average for the day, the long period meters tended to give low indications, and, consequently, high load factors; while, with loads having frequent upward swings, the reverse was usually true. Consequently these meters would sometimes show indications below the average for the day; and in several cases, on widely fluctuating loads, the 60-minute meter of this type gave load factor values of over 100 per cent. This feature is due to the fact that the timing mechanism is operative only during increasing deflections; and, upon a decrease of load below the point corres-

ponding to the position of the wattmeter element of the instrument, this element, quite irrespective of the time period of the instrument, instantly follows the load to its minimum value; and can only climb back again as permitted by the escapement.

5. The load factor, as determined by the logarithmic meters, varied, even on the most fluctuating loads, only a few per cent, between the shortest and the longest time periods.

6. With load curves wherein the peak occurred early in the day, the power having been off, or very low, during the night, the logarithmic meters tended to give readings lower than the true arithmetical peak, giving a higher value of load factor, the discrepancy approximating the difference in reading which might be expected from the "90 per cent" clause in the definition of their time period. But when the peak came late in the day, after a long-continued run, the load factor as given by the logarithmic meter approached the arithmetical load factor, and in some cases acquired a lower average value. This is consistent with the heating of electrical apparatus.

Conclusions

It is manifestly impossible to arrive at any set rules governing the selection or operation of methods or apparatus for the determination of an empirical quantity. Consideration must be given to a variety of local conditions, which, in all probability, would not be duplicated in any two power systems. It is practicable, therefore, to give as conclusions to this study only a number of deductions which will be quite evident to a student of the subject; together with suggestions as to ways and means of overcoming some of the difficulties which have heretofore presented themselves.

1. In the determination of demand it is not feasible to obtain a quantity which will fairly represent all the factors to be taken into consideration. It is probable that the most logical quantity will be found in the volt-amperes of the load.

2. Values of "sustained peak," as determined from the charts of graphic meters are frequently misleading and of little significance.

3. Values of averged or integrated peaks are difficult to measure on graphic meter charts, and are subject to a large personal error.

4. Readings of the Merz or "block interval" type of meters, though in themselves very erratic, will, in the long run, average more closely to the arithmetical average than the indications obtained by any other method.

5. Individual readings of the logarithmic meters are more consistent, and usually clcser to the true value of the arithmetical averages than are the individual readings of the Merz meters.

6. Since heating follows a logarithmic, rather than an arithmetical law, it would seem, where heating is being taken into consideration, that the logarithmic average is fully as justifiable as the arithmetical for a basis of demand measurement.

APPENDIX I.

As the tests were made with a constant voltage on the generator bus during each run it was deemed permissible for purposes of demonstration, to neglect in each case the change in voltage at the receiving end, and to consider the losses due to potential alone as being of a constant value. The expression $K\ E^m$ then becomes a constant, and may be conveniently represented by P.

The expression for the total losses then becomes $W = P + R\ I^2$, and we have only to find values for P and R. Those are easily obtained as follows: By running the system at no load, normal voltage, a value of P is at once obtained by reading the input. Subtracting this from the total power consumption at any desired value of current there is left $W - P = R\ I^2$ in which R represents the equivalent resistance of the circuit, and should be an approximately constant quantity for all values of the load.

The application of the formula with these values for P and R to the curve of amperes should give a curve representing the total losses.

A typical calculation is given below:

Watts at normal voltage, no load,	$= P$	$= 411$
Losses at chosen point	$= W$	$= 605$
Current at same point	$= I$	$= 3.31$

$$\text{Then } R = \frac{W - P}{I^2} = \frac{194}{11.0} = 17.6$$

Under ideal conditions this value, representing the equivalent resistance of the circuit, should, of course, remain nearly constant at all points of the test; but as a number of losses of secondary order have been neglected, and as the voltage was assumed to be constant at all points in the system, a variation of several per cent was, in the actual tests, noted in the value of R.

In obtaining the calculated values for the losses, there was assumed a constant value for R, this value being computed from near the middle point of the original curve, and no consideration taken of possible variations due to changes in the temperature of the copper.

An examination of the curves will show that, considering the assumptions which have been made, the calculated values of total losses check remarkably closely with the actual readings throughout the length of the curve, both on the high and the low power factor loads.

To further demonstrate the applicability of this method, a number of readings were taken at random on different types of loadings with results as shown in the following table.

Condition	W_1	W_2	$W_1 - W_2$	$R I^2 = (W_1 - W_2) - \text{Load } A$	I	I^2	$= RI^2/I^2$
A	400	000	400	000	000	000	....
B	1400	508	892	492	5.36	28.8	17.1
C	820	292	528	128	2.90	8.4	15.2
D	635	46	589	189	3.16	10.0	18.9
E	882	182	700	300	4.23	17.9	16.8
F	1064	296	768	368	4.66	21.8	16.9

W_1 = Watts input
W_2 = Watts output
$W_1 - W_2$ = Total losses
$R I^2$ = Copper losses
I = Secondary amperes
I^2 = Secondary amperes, squared
R = Equivalent resistance of circuit.

Following are the loads:
A:—No load,—excitation only
B —Lamp load only
C —Lamp load only
D —Choke coil alone
E —Choke coil and lamps in series.
F —Choke coil and lamps in multiple.

Taking the constancy of the calculated value of the equivalent resistance as the criterion by which to judge the fitness of the rule, we here find a maximum variation of 12½ per cent. A reversal of the formula and the use of resistance values having even this discrepancy would enable the values of energy loss to be computed from the current values with a far greater degree of accuracy than they could be determined from any series of readings of watts or volt-amperes of the load.

The application of such a scheme of demand measurement to determine heating effects in those portions of the system which supply only one consumer should not present any great difficulty. The two constants used in the formula could be determined for each installation; either by measurement or by calculation from the known characteristics of the lines and transformers. The application of these values to the readings of the ampere demand meter or the ampere-squared demand meter, as the case may be, would then give a check on the energy losses, and therefore, on the heating of the equipment feeding the load under consideration, thus establishing a basis upon which to compute the proportion of the overhead to be borne by that particular customer.

APPENDIX II.

In the following tables will be found the values from which were derived the curves in Figs. 9 to 13. These figures are expressed as watts in the metering circuits, no regard being given to the ratios of the instrument transformers. The values of average watts were obtained by dividing the watt-hours consumed in each day's run by the number of hours constituting the run. The maximum demands are the indications of the respective demand meters, multiplied by the proper constants and corrected for all known sources of error. Load factors were obtained by dividing the average watts for each day by the demand value for that day, as indicated by the meter under consideration. The several load factors determined by a meter of one time period and type for the several day's run were then averaged and the mean of these taken as one of the points upon the final curve.

Attention is here called to the indication of the Siemens meters occasionally being higher than the corresponding reading of the standard instrument, which would not seem in accord with the theories of that instrument. This is due to the uncertainty of the meshing of the gears, which introduced a possible error of about 1 per cent of the full scale of 300 degrees. On some occasions, when the reading was well down on the scale, this error would be greatly magnified, and increase or decrease the reading by several per cent. As all meters of this class are to a greater or less extent subject to this fault, it was taken as one of the characteristics of the type, and no effort made to correct for the inconsistency.

MAXIMUM DEMAND AND LOAD-FACTOR MEASUREMENTS ON TESTING LABORATORY

Type of meter.	Period (mins.)		Day 1	Day 2	Day 3	Average
			Avg. watts. 671	Avg. watts. 824	Avg. watts. 660	
Logarithmic	10	Max. demand.	879	972	742	
		Load factor	76.5	84.9	88.9	83.4
	15	M. D.	858	965	730	
		L. F.	78.2	85.5	90.4	84.7
	30	M. D.	845	947	720	
		L. F.	79.4	87.1	91.6	86.0
	40	M. D.	848	949	712	
		L. F.	79.1	87.0	92.6	86.2
Block Interval	10	M. D.	792	1013	771	
		L. F.	86.7	81.3	85.5	84.5
	20	M. D.	766	990	764	
		L. F.	87.6	83.4	86.4	85.8
	30	M. D.	750	989	754	
		L. F.	89.4	83.4	87.6	86.8
	60	M. D.	758	934	745	
		L. F.	88.5	88.3	88.6	88.5
Mechanically lagged	10	M. D.	945	1040	810	
		L. F.	71.0	79.1	81.5	77.2
	20	M. D.	935	1040	800	
		L. F.	71.7	79.1	82.5	77.7
	30	M. D.	915	1030	795	
		L. F.	73.4	80.0	83.0	78.8
	60	M. D.	920	1000	790	
		L. F.	72.9	82.4	83.6	79.6
Continuous recording	10	M. D.	788	1020	770	
		L. F.	85.1	80.6	85.7	83.8
	20	M. D.	779	989	756	
		L. F.	86.0	83.4	87.4	85.6
	30	M. D.	760	989	750	
		L. F.	88.0	83.4	87.9	86.5
	60	M. D.	736	950	745	
		L. F.	91.1	86.8	88.5	88.8

MAXIMUM DEMAND AND LOAD-FACTOR MEASUREMENTS ON RUBBER MANUFACTURING PLANT

Type of meter.	Period (mins.)		Day 1	Day 2	Day 3	Average
			Avg. watts. 445	Avg. watts. 455	Avg. watts. 440	
Logarithmic	10	Max. demand.	513	545	558	
		Load factor	86.7	83.5	78.7	83.0
	15	M. D.	514	534	545	
		L. F.	86.5	85.1	80.6	84.1
	30	M. D.	510	520	530	
		L. F.	87.2	87.5	83.0	85.9
	40	M. D.	496	504	532	
		L. F	89.6	90.3	82.6	87.5
Block Interval	10	M. D.	551	553	570	
		L. F.	80.8	82.2	77.2	80.1
	20	M. D.	530	547	563	
		L. F.	84.0	83.3	78.2	81.5
	30	M. D.	536	530	550	
		L. F.	83.0	85.8	80.0	82.9
	60	M. D.	513	526	539	
		L. F.	86.8	86.5	81.7	85.0
Mechanically lagged	10	M. D.	615	630	706	
		L. F.	72.4	72.3	62.3	69.0
	20	M. D.	618	624	650	
		L. F.	71.9	72.8	67.7	70.8
	30	M. D.	605	605	624	
		L. F.	73.5	75.2	70.5	73.1
	60	M. D.	588	578	587	
		L. F.	75.7	78.7	75.0	76.5
Continuous recording	10	M. D.	538	570	544	
		L. F.	82.7	79.8	74.0	78.8.
	20	M. D.	533	550	578	
		L. F.	83.5	82.6	76.1	80.7
	30	M. D.	530	538	556	
		L. F.	84.0	84.5	79.1	82.5
	60	M. D.	520	514	556	
		L. F.	85.5	88.5	79.1	84.4

MAXIMUM DEMAND AND LOAD-FACTOR MEASUREMENTS ON BRASS ROLLING MILL

Type of meter.	Period (mins.)		Day 1	Day 2	Day 3	Day 4	Average
			Avg. watts. 572	Avg. watts. 622	Avg. watts. 580	Avg. watts. 590	
Logarithmic	10	Max. demand.	750	800	750	810	
		Load factor	76.2	77.7	77.3	72.8	76.0
	15	M. D.	730	780	745	790	
		L. F.	78.4	79.6	77.8	74.6	77.6
	30	M. D.	695	740	720	765	
		L. F.	81.2	84.0	80.6	77.1	80.7
	40	M. D.	675	748	690	750	
		L. F.	84.8	83.0	84.0	78.6	82.6
Block Interval	10	M. D.	756	832	780	837	
		L. F.	75.5	74.7	74.3	70.4	73.7
	20	M. D.	740	803	761	817	
		L. F.	77.2	77.0	76.1	72.1	75.6
	30	M. D.	730	790	746	789	
		L. F.	78.3	78.7	77.7	74.8	77.4
	60	M. D.	679	750	682	756	
		L. F.	84.2	82.9	85.0	78.0	82.5
Mechanically lagged	10	M. D.	683	750	780	835	
		L. F.	83.7	82.9	74.3	70.7	77.9
	20	M. D.	655	710	710	800	
		L. F.	87.2	87.5	81.6	73.7	82.5
	30	M. D.	600	700	680	750	
		L. F.	95.2	88.8	85.3	78.6	87.0
	60	M. D.	540	620	610	610	
		L. F.	105.8	100.2	95.0	96.6	99.4
Continuous recording	10	M. D.	788	840	780	825	
		L. F.	72.5	74.0	74.3	71.5	73.1
	20	M. D.	750	807	773	802	
		L. F.	76.2	77.0	75.0	73.9	75.5
	30	M. D.	729	775	765	795	
		L. F.	78.5	80.2	75.8	74.2	77.2
	60	M. D.	675	734	727	750	
		L. F.	84.6	84.7	79.7	78.6	81.9

MAXIMUM DEMAND AND LOAD-FACTOR MEASUREMENTS ON MACHINE SHOP

Type of meter.	Period (mins.)		Day 1	Day 2	Average
			Avg. watts. 600	Avg. watts. 777	
Logarithmic	10	Max. demand.	795	1000	76.5
		Load factor	75.3	77.7	76.5
	15	M. D.	805	955	
		L. F.	74.5	81.4	77.9
	30	M. D.	776	900	
		L. F.	77.3	86.4	81.9
	40	M. D.	765	855	
		L. F.	78.4	91.0	84.7
Block Interval	10	M. D.	866	960	
		L. F.	69.3	80.9	75.1
	20	M. D.	842	906	
		L. F.	71.3	86.7	78.5
	30	M. D.	824	908	
		L. F.	72.8	85.5	79.2
	60	M. D.	802	873	
		L. F.	74.7	89.0	81.9
Mechanically lagged	10	M. D.	989	1152	
		L. F.	60.6	67.3	63.9
	20	M. D.	958	1130	
		L. F.	62.6	68.7	65.7
	30	M. D.	945	1130	
		L. F.	63.5	68.7	66.1
	60	M. D.	910	1120	
		L. F.	65.8	69.2	67.5
Continuous recording	10	M. D.	895	1060	
		L. F.	66.9	73.2	70.0
	20	M. D.	852	937	
		L. F.	70.4	82.9	76.7
	30	M. D.	834	913	
		L. F.	72.0	85.0	78.5
	60	M. D.	821	861	
		L. F.	73.0	90.2	81.6

MAXIMUM DEMAND AND LOAD-FACTOR MEASUREMENTS ON CITY TRAMWAY

Type of meter,	Period (mins.)		Day 1	Day 2	Day 3	Day 4	Average
			Avg. watts. 297	Avg. watts. 310	Avg. watts. 491	Avg. watts. 455	
Logarithmic	10	Max. demand.	482	435	809	752	
		Load factor	61.5	71.2	60.7	60.4	63.5
	15	M. D.	497	446	772	715	
		L. F.	59.7	69.6	63.6	63.6	64.1
	30	M. D.	463	428	744	701	
		L. F.	64.0	72.5	65.9	64.9	66.8
	40	M. D.	455	426	703	663	
		L. F.	66.2	72.8	69.7	68.6	69.3
Block Interval	10	M. D.	500	422	746	700	
		L. F.	59.4	73.5	65.0	64.9	65.7
	20	M. D.	490	420	746	704	
		L. F.	60.6	73.8	65.7	64.6	66.2
	30	M. D.	450	410	740	695	
		L. F.	66.0	75.7	66.3	65.4	68.3
	60	M. D.	402	387	669	633	
		L. F.	73.8	80.0	73.5	71.8	74.8
Mechanically lagged	10	M. D.	530	445	790	700	
		L. F.	56.0	69.7	62.2	65.0	63.2
	20	M. D.	495	400	750	585	
		L. F.	60.0	77.5	65.5	77.7	70.0
	30	M. D.	435	350	658	545	
		L. F.	68.5	88.5	74.7	83.4	78.7
	60	M. D.	320	290	550	423	
		L. F	92.8	106.8	89.3	107.5	99.1
Continuous recording	10	M. D.	500	424	782	724	
		L. F.	59.4	73.1	62.8	62.8	64.5
	20	M. D.	479	415	765	710	
		L. F.	62.0	74.6	64.2	64.1	66.2
	30	M. D.	466	408	735	697	
		L. F.	63.8	75.9	66.9	65.2	67.9
	60	M. D.	461	402	708	677	
		L. F.	64.4	77.1	69.4	67.1	69.5

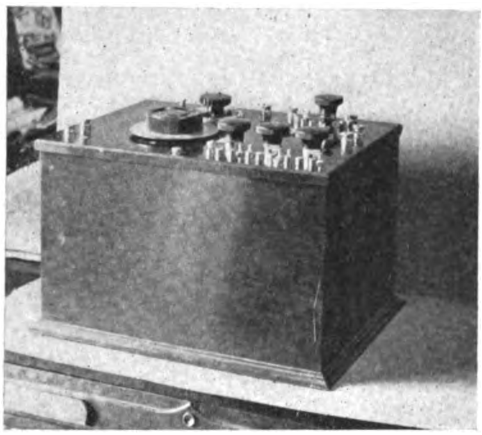
An Audio-Frequency Vacuum-Tube Generator

BY J. A. EYSTER

Electrical Laboratories, Scovill Mfg. Co., Waterbury, Conn.

The use of the three-element vacuum tube for supplying alternating current to a conductivity bridge is described and illustrated. Its advantages are set forth and the procedure which was followed in the construction of such a generator described.

IN using a Wheatstone bridge for measuring the conductivity of solutions we found that sources of alternating current such as the induction alternator and the microphone hummer did not give a pure sine wave nor anything approaching it, so that our measurement of solutions of, say 500 ohms cell resistance could not be relied upon to within more than plus or minus 1 per cent. The present available sources of alternating-current energy suitable for a



bridge are the alternator, the singing telephone or "howler", the microphone hummer, the Vreeland sine wave oscillator, the electric tuning fork and the vacuum tube oscillator. Of these the last is the only one that is capable of giving a perfect sinusoidal current, and at the same time being constant and reliable, with no moving parts and capable of a very wide range of pitch adjustment. Materials were available to set up such a generator for trial, the results of which were so encouraging that we immediately started construction of a self-contained audio-frequency generator. It is the purpose of this article to give the points of greatest difficulty in making such an oscillating set, and to emphasize the most important considerations of design.

The circuit employed was the one using close electromagnetic coupling, as it is one of the easiest to make oscillate as well as being flexible. The objects to be obtained were:

(1) A pure sine wave.

(2) Frequency continuously variable from 1000 cycles per second up to the limit of audibility.

(3) Persistency of oscillation.

(4) Power variation from zero up to several watts.

The pure sine wave is necessary, as explained above. The frequency should be continuously variable to allow tuning to the resonant frequency of the telephone receiver, and to supplement tuning with the condenser used for correcting the power factor of the conductivity bridge. Persistency of oscillation is, of course, necessary for reliability, and power variation is desirable so that the null point will be a true position of no sound, no matter what the resistance of the electrolyte. The inductance should be large and the capacitance small for two reasons, first, because the apparatus will oscillate much more easily, and second, because it is easier and cheaper to make a small capacitance which is continuously variable down to zero. We planned to make a fixed inductance and variable capacity of such sizes that with the maximum capacity the circuit would have a frequency of 1000 cycles. Variable air condensers of 0.005 microfarad capacity are on the market, and a paper condenser of ten times this capacity, variable in ten steps, and capable of standing 500 volts can be made up easily. This we did, giving a total capacity of 0.055 microfarad.

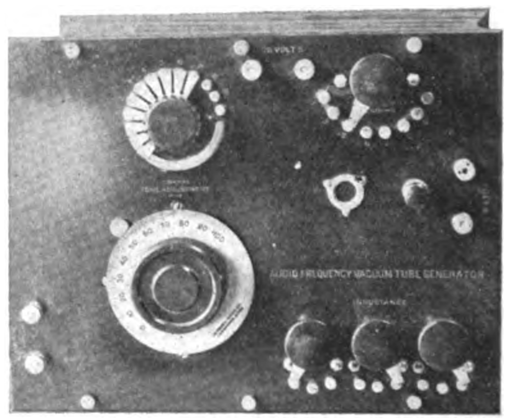
By the formula,

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ (cycles per second)}$$

L is in henrys
C is in farads

the amount of inductance necessary is found to be 542 millihenrys

By experiment we found that the filament tap on the inductance should be taken out at almost exactly the two-thirds point, so we made up a coil of 2400 turns,



taking taps out after 120, 240, 1600,1680, 1760, 2160 and 2280 turns, to be sure of hitting the right point for strongest oscillations and also to give an additional method of adjusting the tone. The grid condenser used was of about 0.01-microfarad capacity, but anything from 0.01 to 2.0 microfarads will do. In order that the tube could be made to oscillate over the wide

range of frequency the grid leak was made variable, but this precaution was found not to have been entirely necessary. A 1.0-megohm leak will suffice over the useful range. The power variation is obtained simply

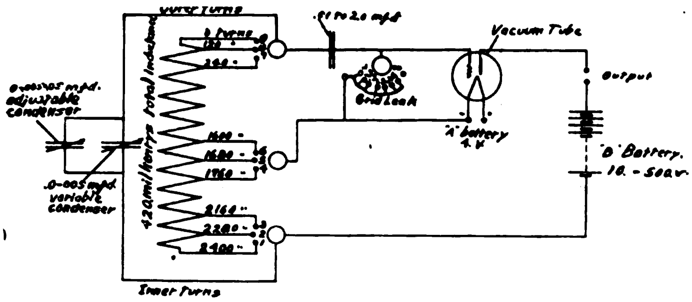


FIG. 1

by changing the "B" battery voltage and the kind of tube. For nearly all purposes the Western Electric tube known as the V. T. 1 will be satisfactory, but for greater power the V. T. 21 may be used. The

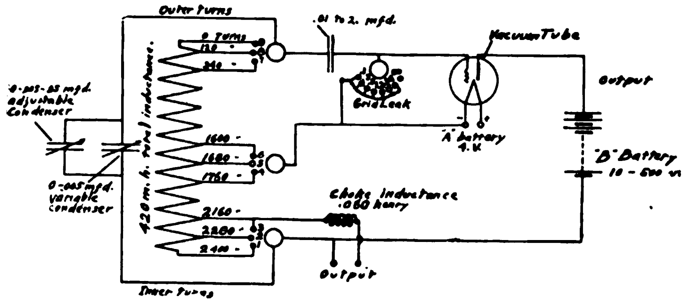
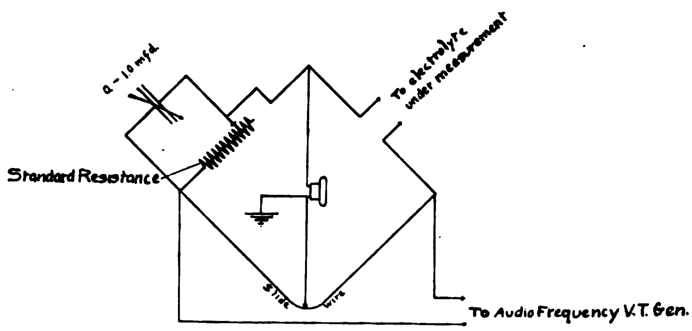


FIG. 2

former has a maximum plate potential of 350 volts, while the latter is designed for 500 volts. In our use of this generator we find it sufficient to use the V. T. 1 with a plate voltage of 75 volts.

As shown in Fig. 1, which is the connection first used, the output is in series with the plate potential. This has several disadvantages, the main one being that the wave shape has voltage characteristics, and is not always sinusoidal. The final connection used, as illustrated in Fig. 2, gives a current wave of pure sine shape. The inductance in series with the output is primarily to prevent a low-resistance receiving circuit from short-circuiting the turns of the inductance which it shunts and stopping the oscillations. It also tends to smooth out any irregularities in the wave form which might possibly exist. If connection between the "B" battery and the bridge circuit is thought to be undesirable two 2-microfarad condensers can



Conductivity Bridge

FIG. 3

be put in the output leads, although it was not found at all necessary.

The output of this generator was observed with the oscillograph and as far as could be seen no higher harmonics existed in it, but the best test is its actual use in the conductivity bridge. There a much better accuracy was obtained than with any other source of current, and the absence of harmonics was demonstrated by the entire absence of sound at the null point. It was not hard, in fact, to measure the most unfavorable kind of electrolyte with an accuracy of plus or minus 0.1 per cent.

100,000 PETITIONS FOR METRIC SYSTEM

The Department of Commerce at Washington, D. C., is now in receipt of over 100,000 petitions from all over the United States urging upon Congress the adoption of the metric system of weights and measures as the exclusive legal standard. When Congress meets next it is anticipated that this vital question will receive extended consideration. The importance of the adoption of the metric system by the United States has been accentuated by the experience of the world war and the present need of extending the international commerce of the United States. Legislators and officials have also become alive to the increased efficiency in manufacture and production that would be made possible by the adoption of the simple decimal system of weights and measures.

Although strenuous efforts have been made by one or two organizations to stem the tide of growing metric sentiment, it is interesting to note that in contrast to the 100,000 petitions favoring metric standardization there are on file in Washington a relatively small number of petitions against this move. Not more than 1 or 2 per cent of the total number are against metric standardization. Between 98 and 99 per cent urge the advance.

Government officials whose business it has been to study this question are almost unanimous in favoring the metric system. Among staunch supporters of the metric system are William C. Redfield, Franklin K. Lane, J. W. Alexander, present Secretary of Commerce, W. B. Wilson, Secretary of Labor, Franklin D. Roosevelt, Assistant Secretary of the Navy, William G. McAdoo, John Barton Payne, and many others, including members of the Senate and House of Representatives.

A New Electrical Precipitation Treater

BY MOTOJI SHIBUSAWA and YASUJIRO NIWA

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This article gives the description and theory of a new electrical precipitation treater, with results of experimental work in laboratories. The paper contains:

1. *General Description of the New Precipitation Treater; with Glass-Covered Electrodes.*
2. *Experiments at the Electrotechnical Laboratory, Tokyo, Japan.*
3. *Experiments at the Copper Refining Factory at Nikko.*
4. *Field of Practical Application of the New Precipitation Treaters.*
5. *Theory of the New Treater.*
   - *A. Potential Gradient in the Treater, Statically Solved.*
   - *B. Observed Potential Gradient in the Treater.*
   - *C. Passage of Current through the Glass.*
     - *a. Variation of Resistivity of Glass with Temperature.*
     - *b. Variation of Resistivity of Glass with Potential Gradient.*
     - *c. Free Charges on the Glass Surface.*
     - *d. Numerical Calculation on the Treater used in Oscillographic Study.*
     - *e. Conclusions.*

DURING the last ten years since the Cottrell system of precipitating dust in gases was first applied at the Selby Smelting and Lead Co. at San Francisco Bay, the system has made remarkable progress in its practical application.

It will not be amiss to describe here briefly the present extent of the application of electrical precipitation in Japan.

The following eight treaters have been built and are now working:

A. Asano Portland Cement Company (Tokyo Factory).............. 2 sets.
B. Ashio Smelter, Furukawa Mining Company.................. 2 sets.
C. Kaimoka Smelter, Mitsui Mining Company.................. 1 set.
D. Naoshima Smelter, Mitsubishi Mining Company................ 1 set.
E. Ikuno Smelter, Mitsubishi Mining Company.................. 1 set.
F. Nikko Electrolytic Copper Refining Factory, Furukawa Mining Company........................ 1 set.

The Metallurgical Research Institute, Tokyo, has the Cottrell patent rights in Japan and the comparatively rapid progress in this country is largely due to the engineers of this Institute. Beside the factories above mentioned, it is reported that the Institute has submitted designs and specifications of treaters for the Imperial Mint, Shikama Alum Factory, Kanto Sano Alkali Works, Hokkaido Iron and Steel Works and the Fujita Mining Co., etc. The details of the treaters already built are tabulated under:

	A No. 1	A No. 2	B No. 1	B No. 2	C	D	E	F
Nature of gas	Rotary kiln flue gas	Lime kiln flue gas	Mixed gas from roasters blast furnaces and converters of copper smelter	Reverberatory furnace gas	Mixed gas from blast furnaces and other refining furnaces and kettle of lead smelter	Mixed gas from lead smelting furnace and converters from cu. smelter	Gas from blast furnaces smelting copper ores	Gases from cupellation and reduction furnaces
Date started	Dec. 25th, 1917.	Dec. 25th, 1917.	May 10th, 1918.	April 1st, 1919.	June 10th, 1918.	March 1st, 1919.	Feb. 20th, 1919.	May 1st, 1919.
Vol. of gas treated (cu. ft. per min.)	70,000	50,000	180,000	35,000	20,000	50,000	25,000	6,500
Passive electrode diam. by length	12 in. by 16 ft.	12 in. by 16 ft.	12 in. by 16 ft.	12 in. by 16 ft.	12.5 in. by 16 ft.	12.5 in. by 16 ft.	12.5 in. by 16 ft.	12.5 in. by 16 ft.
Number	288	192	640	192	192	320	128	32
Active electrode	No. 14 wire	No. 14 wire	chain	chain	chain	chain	chain	No. 14 wire
No. of rectifier sets	2	1	6	2	3	3	2	1
Precipitation voltage	50,000	60,000	75,000	75,000	70,000	65,000	80,000	70,000
Temp. of gas	250 deg. cent.-300 deg. cent.	80 deg. cent.	....	....	....	....	50 deg. cent.	50 deg. cent.-100 deg. cent.
Amount of precipitates per day	8–10 tons	....	6–10 tons	....	1–1.5 tons	1.5 tons	0.6 ton	200 lb.
Precipitation efficiency (per cent)	95	80–90	70–90 depending on furnace condition.	....	80	95	95	95
Average power for precipitation	12 kw.	....	30 kw.	30 kw.	6 kw.	....	....	2.5–5 kw.
Installation cost. (yen)	461,500		438,126	149,761	101,000	99,000	196,900	23,359

In the modern precipitation treater, the electrodes consist of a metal cylinder as the passive electrode and a bare wire or a metal chain supported along the center of the cylinder as the active electrode.

In such treaters, however, the electrodes are often acted upon by corrosive precipitated particles when the system is applied for gases from smelting furnaces or other corrosive gases such as are produced in some electrochemical works; and consequently the life of the active electrode is shortened excessively; furthermore sparking often occurs between the electrodes, which prevents application to combustible substances and also sometimes causes damage to the transformer. These obstacles hinder the development of electrical precipitation, especially in its new field of application.

The authors have contrived devices in connection with the modern precipitation treater to overcome these obstacles, which have proved successful in both the laboratory and the factory.

1. General Description of the new Precipitation Treater; Treater with Glass-Covered Electrodes

The modern precipitation treater has the following demerits:

(1) The particles are more or less deposited on the active electrodes and, causing back ionization, lower the efficiency of precipitation and uneven loading of the treaters and the amputation of the active conductor by sparking.

(2) The active electrode cannot bear corrosive gas unless a certain kind of alloy wires is used.

(3) It often causes sparking between the electrodes, with subsequent troubles in operation.

In the early type of precipitation treater, sometimes insulating pieces, such as mica, are attached to the active electrode but it is not entirely covered with insulating material, and the attached pieces are used for the purpose of increasing the brush discharge and the precipitation efficiency. With this type of treater precipitation is made by surface leakage, as far as we know.

On the other hand, the fact that the air in the crevice of the power line insulator is subjected to a much higher potential gradient than when the insulating substance is absent, suggested to the authors the possibility that the high potential might ionize the air across the insulating medium of higher specific inductive capacity and that electrical precipitation might be possible even with electrodes entirely covered with insulating material such as glass, etc. The authors, therefore, carried out experiments in the Electrotechnical Laboratory in Tokyo and succeeded in their laboratory experiments, the results of which were published in November 1917, at the Faraday Convention of Japanese Electrical Society.

Recently, the system was practically applied to the treater at the Nikko Copper Refining Works where about 6500 cu. ft. of roaster gas is treated per minute, with satisfactory results.

The authors' treater, as in the case of the modern type, consists of a metal cylinder as the passive electrode and a metal wire suspended along the center of the cylinder as the active electrode; the only difference being, that the electrodes in their treater are entirely separated with dielectric substances such as glass, porcelain, etc. In the experiments at the Electrotechnical Laboratory, both the active and passive electrodes were covered with glass, but at the factory only the active electrodes were so covered.

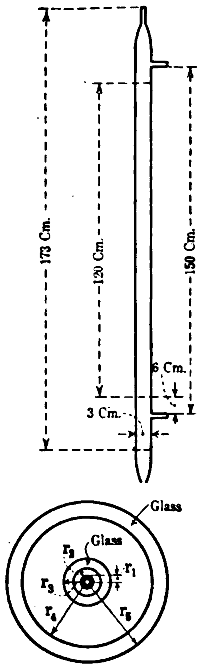

Fig. 1—Section of the Treater

r_1 = 0.35 mm.
r_2 = 1. mm.
r_3 = 2. mm.
r_4 = 14. mm.
r_5 = 15. mm.

2. Experiments at the Electrotechnical Laboratory

For the purpose of oscillographic study the following experiments were carried out at the Electrotechnical Laboratory, Tokyo.

As the active electrode a copper wire covered with dielectric material, and as the passive electrode a glass cylinder covered externally with tin foil were used. The active electrode was supported along nearly the center line of the cylinder.

Fumes of ammonium chloride were passed through this treater and a known quantity of fumes was aspirated from the side tubes attached to the upper and lower ends of the treater and the contents of chlorine were analysed, from which the precipitation efficiency was calculated.

Oscillograms were also taken in this experiment.

The dielectrics used were glass, rubber, porcelain and micanite tube, all of which gave good results, although the voltages to start precipitation were not equal owing to the difference in the nature and size of dielectrics.

The following illustrations show the result of the experiments made with glass-covered electrodes. The dimensions of the electrodes are shown in Fig. 1. Oscillograms taken are shown in Figs. 2 to 13. The circuit connection for each experiment is shown in the accompanying skeleton diagram. In every case we see more or less discontinuous increase in the current through the glass, especially remarkable in Figs. 6 and 7.

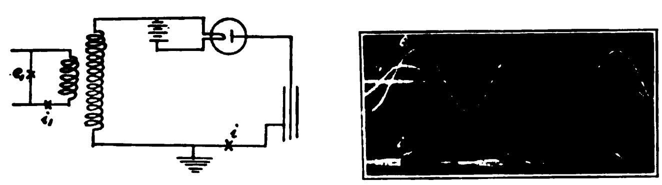

Fig. 2

Wire-negative
i = 0.2 milliampere
e = 26,000 volts.

Fig. 11 shows the same feature in the charging current of the parallel plate condenser, Fig. 12 of the glass condenser and Fig. 13 of the mica condenser. The reason for this sudden increase of current, the authors will discuss further on.

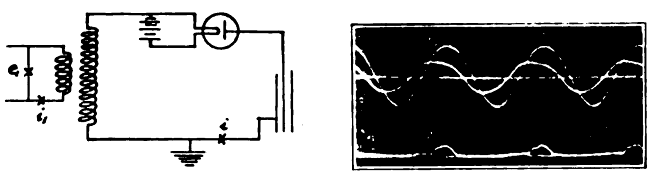

Fig. 3
Wire-negative
i = 0.2 milliampere
e = 26,000 volts.
Fume stopped.

3. Experiments at the Copper Refining Factory at Nikko

Furukawa Mining Co. Ltd. has a Copper Refining Factory at Nikko, a summer resort in Japan famous for its beautiful scenery, where about 50,000 tons of copper per annum, one-third of which being drawn to wires, are electrically refined.

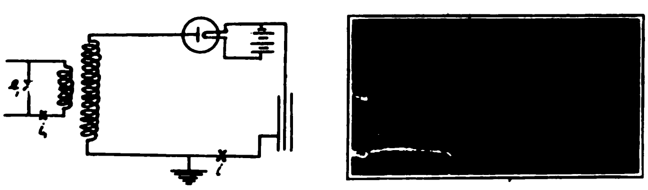

Fig. 4
Wire-positive
i = 0.2 milliampere
e = 26,000 volts.

The factory has recently installed an electrical precipitation plant in order to recover precious particles in the mixed gas from roasting cupellation, reduction and reverberatory furnaces which are used for the purpose of separating silver and gold from slimes precipitated in electrolytic baths. The treater consists of one section of 32 pipes, arranged in a rectangle 8 by 4.

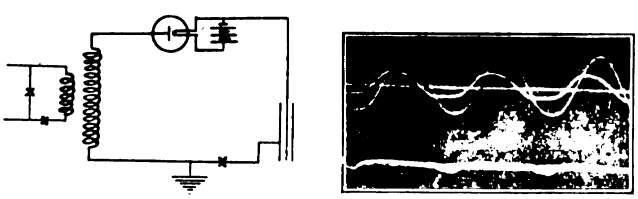

Fig. 5
Wire-positive.
i = 0.2 milliampere.
e = 26,000 volts.
Fume stopped.

These pipes, manufactured by the Western Pipe and Steel Company, are 12.5 inches inside diameter by 16 feet long and are made of No. 14 gage steel plates. The active electrode is No. 14 steel wire stretched concentrically from the lattice work. The treater was designed, at the Metallurgical Research Institute, to handle a gas volume of 8200 cubic feet per minute. But the actual volume is about 6500 cubic feet per minute and is drawn through the treater by an exhaust fan. The temperature of the gas is dependent on the furnace condition.

The roaster and cupellation furnaces are operating daily whereas the reduction and reverberatory furnaces are worked intermittently; so that the gas temperature is usually considerably below 100 deg. cent. and in the latter case only does it rise above 100 deg. cent. The electrical equipment consists of a 10-kv-a., 50-cycle, 200 to 100,000-volt transformer, manufactured by the American Transformer Company, and a rectifier of the rotary arm type, 30 inches in diameter, supplied by the Research Corporation of New York. The rectifier is driven by a 1.5-h.p., 200-volt, three-phase Westinghouse synchronous induction motor. The transformer has taps on the low-tension windings giving voltages of 50,000, 62,500, 87,500 and 100,000 on the secondary circuit. These taps, together with a rheostat in the transformer primary circuit, are sufficient to produce any desired voltage.

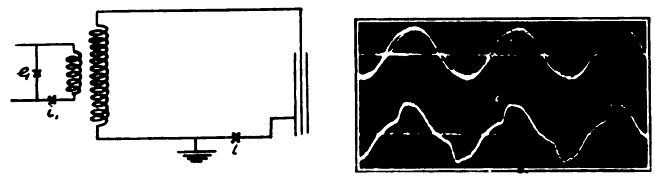

Fig. 6
Alternating current
e = 18,000 volts

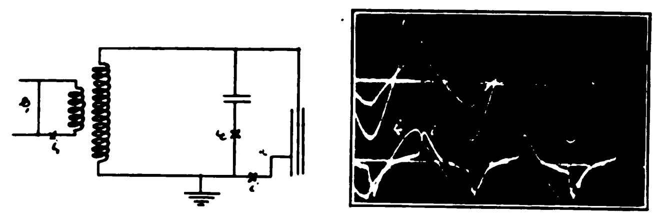

Fig. 7
Alternating current.
e = 18,000 volts.

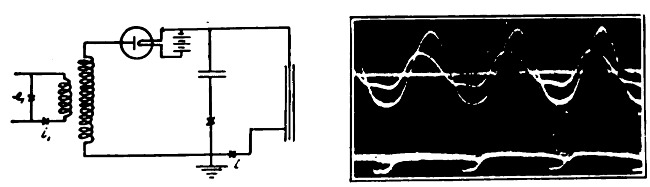

Fig. 8
Wire-positive
i = 0.3 milliampere.
e = 30,000 volts.

Fig. 14 shows an external view of the treater chamber.

From August 25, 1919 to the middle of October, the authors' devices were used in the treater at this factory. The active electrodes are covered with soda glass tubes of chemical laboratory use. The outer diameters of the tubes are 3/8 to 1/4 inch and the thicknesses 1/16

to 1/8 inch. Four such tubes were sufficient to cover the entire length of the electrode. No means for sealing the ends and junctions of the glass tubes were taken. The working results of this treater are briefly described in the following.

(1.) *Vibration of the active electrode and frequent sparking between the electrodes.* It is a well-known fact

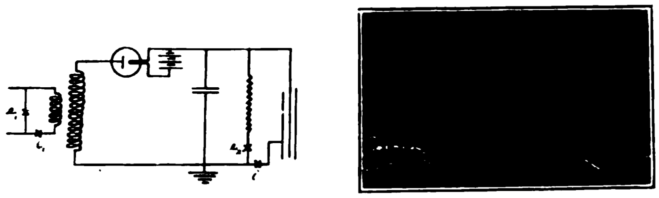

Fig. 9
Wire-positive.
i = 0.1 milliampere.
= 38,000 volts.

that the periodical static force acts on the electrodes of the treater and often causes vibration of the active electrode, especially when the electrode is more or less slackened or is not stretched concentrically; such vibration of the electrodes is one of the chief causes of sparking and consequently amputation of the active electrode. In this factory, the same troubles were

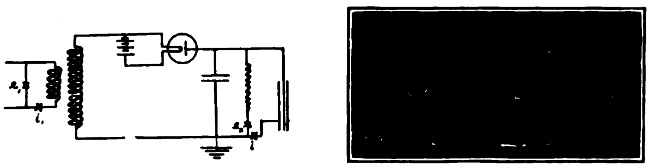

Fig. 10
Wire-negative.
i = 0.2 milliampere.
e_2 = 38,000 volts.

experienced, that is, the active electrodes were vibrated by statical force and caused much trouble.

The engineer was thus obliged to devote much time to find suitable devices to stop this vibration, and he finally succeeded in some measure; but he could not stop it completely. Nevertheless since the active electrodes were covered with glass tubes, the vibration

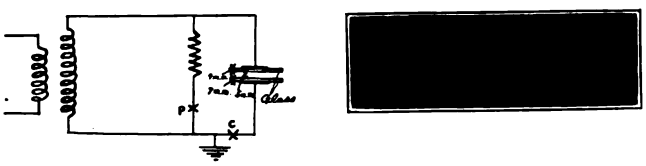

Fig. 11
Electrode area 900 cm.²
Applied voltage 20,000

had entirely ceased and practically no sparking occurred.

(2) *Deposits of dust on the active electrodes.* The dust is usually to be precipitated on the passive electrodes, for the dust deposited on the active electrodes is not easily collected in the hopper by hammering but often becomes the cause of uneven corona discharge and consequently eddies of gas around the active electrodes, and decreases the efficiency of precipitation. Therefore it is good practise to keep the deposits on the active electrode as small as possible. In this factory also much dust was deposited on the active electrodes which could not be cleaned by hammering. The authors have always been of the opinion that the deposits on

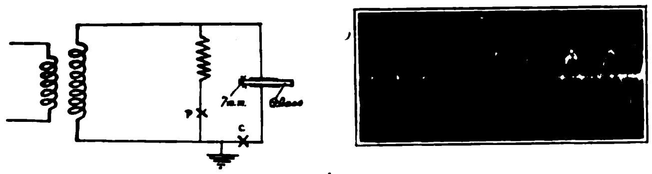

Fig. 12
Electrode area 900 cm.²
Applied voltage 18,000

the active electrodes could be considerably diminished by covering the electrodes with glass; and this has been clearly proved by the experiments at this factory. The construction of the treater chamber prevented frequent inspection of the active electrodes, but when

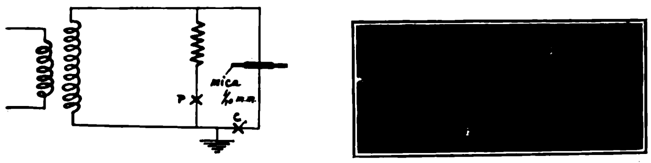

Fig. 13
Electrode area 75 cm.²
Applied voltage 5000

the electrodes were inspected two weeks after the adoption of glass-covered electrodes, it was found that they were very clean and practically no deposit was noticed on the active electrodes.

Since then, the contents of sulphuric acid in the gas

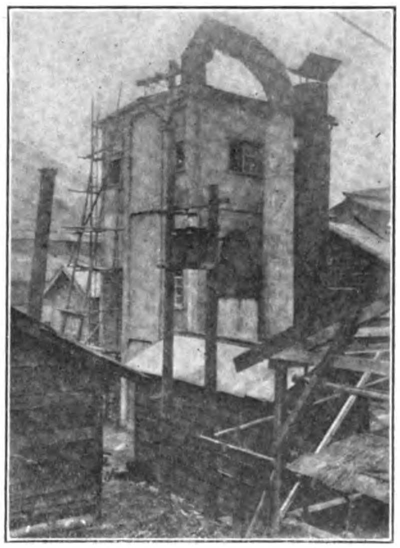

Fig. 14—External Vew of the Treater Chamber at the Copper Refining Factory at Nikko, Japan

from the furnace were increased considerably and the dust became very adhesive, and when the electrodes were inspected one month after use, the active electrodes were found to have some dust deposited on them, especially on the upper part of each electrode

near the top of the cylinder, but practically none on the lower part. The quantity deposited, was, however, very much less than when bare wire was used as the active electrode.

(3) *Corona condition.* The positive and negative corona have different features, especially in their appearance of glow. More or less evenly spaced beads are on the negative corona, whereas the positive corona has the appearance, if not roughed by points, of a smooth glow. This difference can be seen in the corona

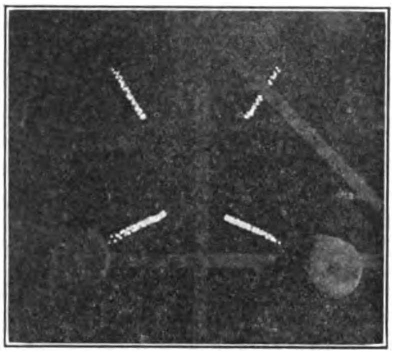

FIG. 15—NEGATIVE CORONA

around the active electrode of the treater. For negative polarity more or less evenly spaced distinct beads are seen on the wire, while for positive polarity a uniform thick glow appears as long as the wire is kept clean, but if the surface of the active electrode is spoiled the glow becomes somewhat similar to the negative corona. For bare steel wire electrodes, it is very difficult to keep the surface clean, and usually glow

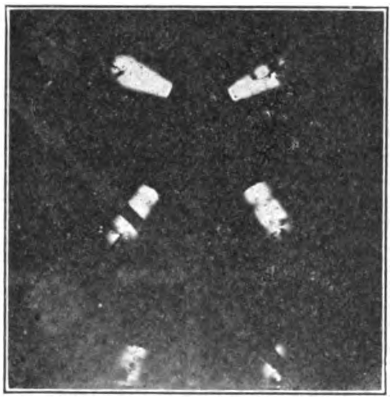

FIG. 16—POSITIVE CORONA

beads appear on the active electrodes even for positive polarity. But, since the electrodes have been covered with glass tubes, the positive glow has become very uniform and this condition has lasted for more than two weeks. Fig. 15 shows negative corona and Fig. 16 the positive corona on the glass-covered active electrodes at the working voltage. The photographs were taken one month after the use of glass covering and when the conditions were unfavorable, for the surface had been somewhat spoiled by the deposited dust, and yet almost a smooth glow can be seen all along the positive electrode.

(4) *Current, input and precipitation efficiency.* In order to test the effect of the glass covering on current, input and precipitation efficiency of the treater, the

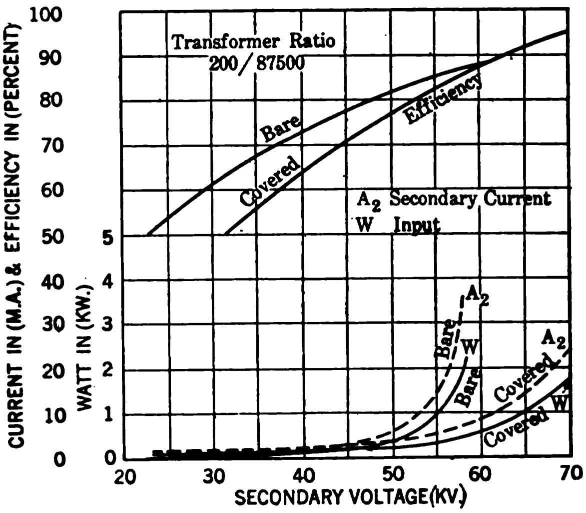

FIG. 17

following tests were made on September 26, 1919. To the treater with glass-covered electrodes, the mixed gas from two cupellation furnaces and one roaster was passed.

The temperature of the gas was 54 deg. cent. at the inlet and 38 deg. cent. at the outlet of the treater. Changing the applied voltage gradually, the corresponding current and input were measured. The precipitation efficiency was also measured with the eyes by

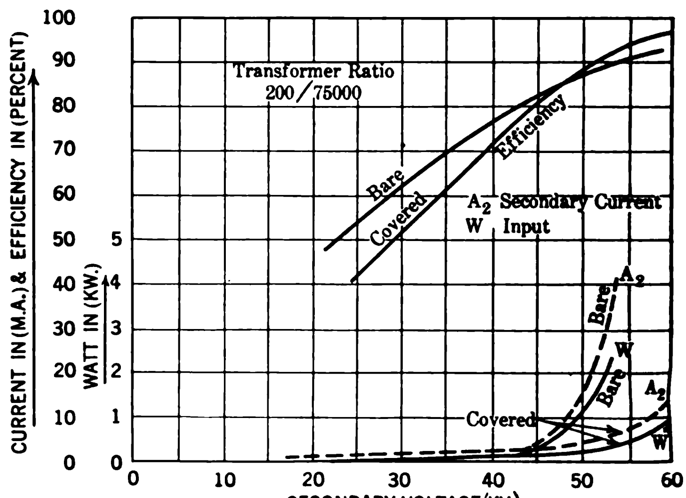

FIG. 18

an experienced engineer at the factory. These were compared with the data for a treater with bare electrodes, taken before the electrodes were covered with glass. The furnace conditions during these two experiments were of course kept as equal as possible. Figs. 17 and 18 show current, input and precipitation

efficiency as ordinates, with high-tension voltage, calculated from ratio of turns and primary voltage, as abscissas.

Comparing these two results, we find that current and input are much diminished by covering the electrodes with glass; the precipitation efficiency for the glass-covered electrodes being less than that for bare electrodes at voltages below a certain value (about 50,000 volts); but at voltages above this limit, the efficiency is much increased and moreover the final efficiency is high. Therefore we must increase applied voltage for glass-covered electrodes, and yet the current and input can be kept much below the values for bare electrodes. From Fig. 18 it will be seen that for bare electrodes at 50,000 volts, the efficiency is 87 per cent and the input 1.2 kw., whereas for glass-covered electrodes at 55,000 volts, increased by 10 per cent in voltage, the efficiency is 94 per cent and the input 0.5 kw. which shows considerable saving of power.

(5) *Conclusions.*

a. By covering the electrodes with glass, vibration of the active electrode and sparking between the electrodes are much diminished, which may prevent surging and damage to the transformer.

b. By covering the active electrodes with glass, the deposit of dust on the active electrode is much decreased; which not only facilitates maintenance, but also makes the corona discharge uniform, thus increasing the precipitation efficiency.

c. By covering the active electrodes with glass, the current and input are much diminished and also the precipitation efficiency increased. For large units of precipitation treater the power cost becomes the principal item of the running expenses, and consequently the saving of power effected by using the glass covering is assuredly a great advantage of the new treater, especially where the power cost is high.

d. One of the difficulties met with in actual operation of the modern treater is the cleaning of the deposits on the electrodes.

By the usual method such as hammering, the electrodes can not be thoroughly cleaned, especially the active electrodes, so that usually the treater is swept by hand, necessitating the workman's entering the treater.

This, of couse, is very unpleasant for the workman, especially when the precipitates contain poisonous compositions such as arsenic, selenium, etc.; so that the work is naturally shirked. By covering the electrodes with glass, precipitates on the active electrodes are considerably diminished and the necessity of frequent sweeping is obviated. Furthermore, it is possible to keep the active electrodes clean by replacing the glass covering. These are great advantages in actual operation.

e. In the experiments at the Nikko Copper Refining Factory, it was proved that the glass-covered treater could be operated successfully at a temperature below 100 deg. cent. Whether the glass can stand more than this temperature, is a question which can be determined by experiments. But excepting some special gases, such as cement kiln gas or the like, the temperature of the gas to be treated in the precipitation treater is generally below 100 deg. cent., and therefore even with the above test it shows that the glass covering may be applied for many practical cases.

f. It was feared that the glass might be broken into pieces in hammering, but this fear proved to be groundless. The covering glass showed no deterioration whatever during two months; after which period the experiments at the factory had to be stopped and the covering removed.

g. The cost of the covering glass is not an important item, for the glass to cover 32 active electrodes 16 feet long may be had for a few dollars.

The authors wish here to express their hearty thanks to Mr. S. Takenaks, the Electrical Engineer of the Copper Refining Factory at Nikko, for his kind courtesy throughout their factory experiments.

4. Fields of Practical Application of the New Precipitation Treaters

The chief merits of the new precipitation treater are enumerated below:

(1) Electrodes are not attacked by corrosive precipitates or fumes.

(2) High potential may be applied without sparking within limited space thus promoting precipitation.

(3) The active electrode may easily be kept clean, which lessens the chances of sparking.

(4) Compared with the modern type of treater, although the applied voltage must be somewhat increased current and wattage are very small and yet the precipitation efficiency is high.

Therefore the new precipitation treater, possessing these advantages is eminently suited for application in the following fields:

a. Very corrosive gases to be treated;

b. Very moist gases to be treated;

c. Dust containing combustible substances to be treated.

This new treater may thus be successfully used in order to precipitate acid particles from gases in acid works, to obtain concentric acid by spraying steam into acid gas and precipitating electrically, to precipitate inflammable materials from smelter gases and to separate cotton dust in spinning factories.

5. Theory of the New Treater

The theoretical aspect of electrical precipitation is to be attacked on the base of electrodynamical as well as electrostatical standpoint. The study of this point of view is now pursued but only the parts concerning the authors' new treater will be described here.

First of all the authors treated the potential gradient in their treater statically, and then determined experimentally the actual potential gradient in the treater.

The results showed quite different features from those calculated statically.

The most important and interesting problem regarding the authors' treater is the investigation of how current passes through glass. The authors made several experiments, which are described in the latter half of this section, to solve the question.

A. Potential Gradient in the Treater Statically Solved. The potential gradient in the treater statically solved possesses different features as compared with the actual potential gradient, and it is doubtful what practical use such solution has in the actual treater. But the suggestion of their new treater was obtained by the authors from the potential gradient statically solved in the cylinder with and without glass covering, and therefore the solution on the basis of electrostatics will be first briefly described.

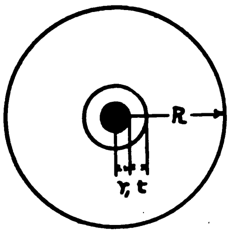

Fig. 19

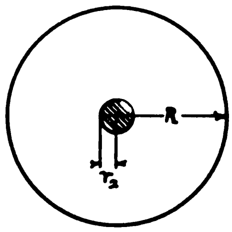

Fig. 20

First, comparison will be made of the potential gradient in the treaters with and without glass covering, a section of which is shown in Fig. 19 and in Fig. 20. The treater with glass covering will be called No. 1 treater, and the ordinary treater, No. 2 treater.

Let X_1 = potential gradient at a point X apart from the center in No. 1 treater.

X_2 = do. in No. 2 treater.

r_1 = radius of active electrode of No. 1 treater.

r_2 = do. of No. 2 treater,

R = radius of passive electrode, assumed equal for both treaters,

t = thickness of glass covering of active electrode of No. 1 treater,

K = dielectric constant of gas,

K' = dielectric constant of glass,

E_1 = applied voltage for No. 1 treater

E_2 = do. for No. 2. treater.

Then the intensities in these two treaters at the point distance X from the center are respectively:

$$X_1 = \frac{E_1}{X K\left[\frac{1}{K'}\log_e \frac{r_1+t}{r_1} + \frac{1}{K}\log_e \frac{R}{r_1+t}\right]} \tag{1}$$

$$X_2 = \left[\frac{1}{X K}\ \frac{E_2}{\frac{1}{K}\log_e \frac{R}{r_2}}\right] \tag{2}$$

If $E_1 = E_2$, then

$$\frac{X_2}{X_1} = \frac{\frac{1}{K'}\log_e \frac{r_1+t}{r_1} + \frac{1}{K}\log_e \frac{R}{r_1+t}}{\frac{1}{K}\log_e \frac{R}{r_2}} \tag{3}$$

or

$$\frac{X_2}{X_1} = 1 + \frac{1}{\log_e\left(\frac{R}{r_2}\right)^{1/K}} \log_e\left(\frac{r_1+t}{r_1}\right)^{1/K'} \times \left(\frac{r_2}{r_1+t}\right)^{1/K}$$

Therefore if

$$\left(\frac{r_1+t}{r_1}\right)^{1/K'}\left(\frac{r_2}{r_1+t}\right)^{1/K} \leqq 1$$

or

$$\left(1+\frac{t}{r_1}\right)^{1/K'}\left[\frac{r_2}{r_1\left(1+\frac{t}{r_1}\right)}\right]^{1/K} \leqq 1$$

or

$$\left(1+\frac{t}{r_1}\right)^{1/K'-1/K} \times \left(\frac{r_2}{r_1}\right)^{1/K} \leqq 1$$

Then

$$\frac{X_2}{X_1} \leqq 1$$

Usually K' (dielectric constant of glass) is greater than K (dielectric constant of gas) and therefore for equal active electrodes, or $r_1 = r_2$ above relation is always satisfied for all values of t; that is the intensity may be increased by covering the active electrode with glass. Next we will compare the maximum potential gradient in these two treaters, which, of course ought to be at the contact surface between the gas and the inner electrode. The maximum values may be obtained by putting $x = r_1 + t$ in expression (1) and $x_2 = r_2$ in expression (2). Thus

$$\frac{X_{2m}}{X_{1m}} = \frac{E_2}{E_1} \times \frac{(r_1+t)}{r_2} \times \frac{\log_e\left(\frac{r_1+t}{r_1}\right)^{1/K'}\left(\frac{R}{r_1+t}\right)^{1/K}}{\log_e\left(\frac{R}{r_2}\right)^{1/K}} \tag{4}$$

Now, suppose the applied voltage is raised until the same maximum potential gradient is attained, even with glass covering, the voltage will be given by, equating expression (4) to unity, thus

$$E_1 = \left(\frac{r_1+t}{r_2}\right)$$

$$\times \frac{\log_e\left(\frac{r_1+t}{r_1}\right)^{1/\kappa'}\left(\frac{R}{r_1+t}\right)^{1/\kappa}}{\log_e\left(\frac{R}{r_2}\right)^{1/\kappa}} \times E_2 \quad (5)$$

Applying these voltages to each treater respectively, the ratio of the potential gradients at any point of both the treaters equidistant from the center becomes

$$\frac{X_2}{X_1} = \frac{\log_e\left(\frac{r_1+t}{r_1}\right)^{1/\kappa'}\left(\frac{R}{r_1+t}\right)^{1/\kappa}}{\log_e\left(\frac{R}{r_2}\right)^{1/\kappa}} \times \frac{E_2}{E_1} \quad (6)$$

Substituting (5) in (6) we have

$$\frac{X_2}{X_1} = \frac{r_2}{r_1+t} \quad \text{or} \quad X_1 = \frac{r_1+t}{r_2} \times X_2$$

Thus by raising the applied voltage in No. 1 treater to

$$\left(\frac{r_1+t}{r_2}\right)\left[\frac{\log_e\left(\frac{r_1+t}{r_1}\right)^{1/\kappa'}\left(\frac{R}{r_1+t}\right)^{1/\kappa}}{\log_e\left(\frac{R}{r_2}\right)^{1/\kappa}}\right] \quad (5)$$

times the voltage in No. 2 treater, we may increase the potential gradient in the gas in No. 1 treater by $\frac{r_1+t}{r_2}$ times the value in No. 2 treater, keeping the maximum potential gradient at constant.

But the expression in the large brackets in (5) is the same as (3) which is less than unity for equal active electrodes and for all values of t, which means that the potential in the No. 1 treater is increased, keeping the maximum potential gradient constant, by a ratio more than the value by which we raised the applied voltage.

One more important item to be considered is that with the glass covering there is less chance of sparking between electrodes and thus we may conclude that the intensity in the treater may be increased, keeping the maximum potential gradient at constant, with a safer condition with regard to the sparking between electrodes.

In Fig. 21 A is the potential curve in the treater with

r_1 = 0.45 mm.
R = 15 mm.
K = 1
E = 10,000 volts.

When the active electrode of this treater is covered with the dielectric substance of thickness 0.95 mm. having a dielectric constant of 2.5, the potential gradient in the treater will become as shown in curve B. Now, in order to increase the maximum potential gradient in the gas to the same value in curve A, the applied voltage must be increased to 32,000 and the corresponding potential gradient is expressed in curve C, which shows that the potential gradient in the gas is much increased as compared with the curve A.

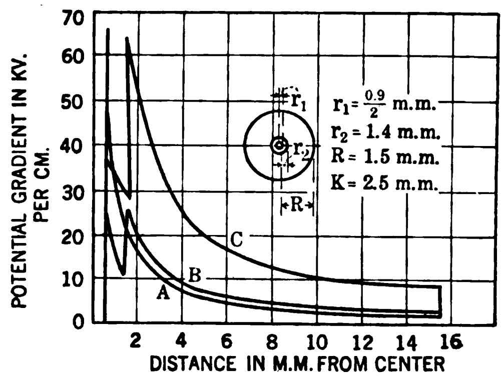

Fig. 21

B. Observed Potential Gradient in the Treater.

The electrical precipitation is done by the migration of charged particles and the presence of charged particles in the treater necessarily changes the potential gradients in the treater.

In order to obtain the actual potential curve in the treater, the authors made the following experiment. The connection diagram of the experiment is shown in Fig. 22.

T is the 100-160,000-volt, 20-kv-a. testing transformer; K, the 40,000-volt kenotron made at the Electrotechnical Laboratory; and U, the treater with glass covering, a section of which is shown in

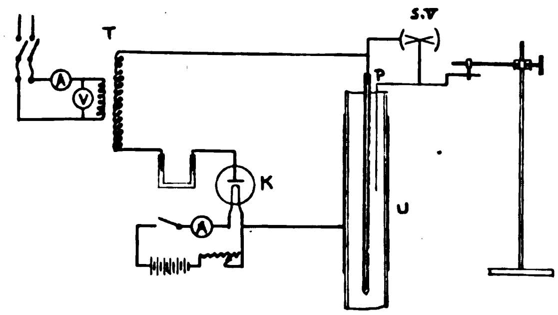

Fig. 22

Fig. 24A. One end of the glass tube being sealed, salt water was poured into it and used as the active electrode. As the passive electrode, tin foils stuck to the outer surface of the glass tube were used.

High voltage was applied to the treater through the kenotron, and a Kelvin static voltmeter (s. v.) was connected between the active electrode and the pointer, P, which was gradually displaced by turning the pulley, from the active to the passive electrode, keeping always parallel to the electrodes. The mechanism is shown in Fig. 23. The potential difference between the active electrode and any point in the treater was

measured by the static voltmeter. In this manner the potential curves in the treater were obtained; one of these curves which corresponds to the maximum voltage of 8500 is shown in Fig. 24. The potential gradient curve in the treater was obtained from the potential curve, which has different features from the curve calculated statically. As the reading of the static voltmeter is the square root of the mean of the

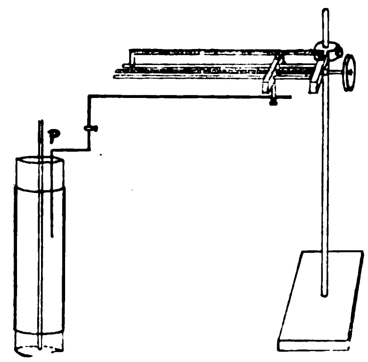

Fig. 23

half wave taken over the whole period, correction was made assuming the wave sinusoidal. Let E and E_m be the voltmeter reading and the maximum voltage

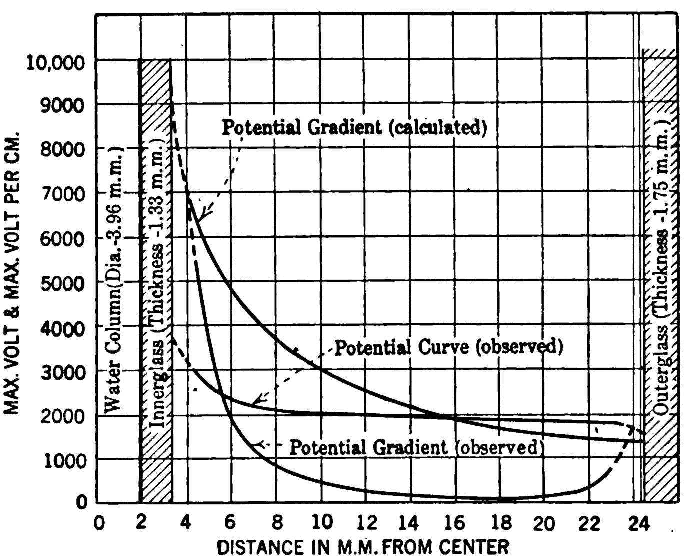

Fig. 24

respectively; then

$$E^2 = \frac{1}{2\pi}\int_0^{\pi} E_m^2 \sin^2\theta \, d\,\theta$$

$$\text{or} \quad E^2 = \frac{E_m^2}{2\pi} \times \frac{\pi}{2} \qquad \therefore \quad E_m = 2E.$$

In Fig. 24 the pulsating voltage is expressed in its maximum value using this correction factor. As may be seen in the figure existence of the charged ions or particles in the treater causes a zone of high potential gradient at the boundary of the passive electrode, and lowers the potential gradient in the space between the electrodes. As the pointer used in this experiment had a diameter of 1 mm., the potential difference at the extreme boundary to the electrode will be higher than the value in Fig. 24. Moreover, the capacity of the static voltmeter, although very small, will disturb the condition, and may introduce some error in the results.

Mr. H. T. Booth published also an experimental result upon the potential curve for the treater without glass covering which shows the same feature as that in Fig. 24. (cf. Distribution of Potential in a Corona Tube. *Physical Review.* Sept. 1917.)

C. Passage of Current through the Glass.

In the early experiments on their treater the authors found that the current through the glass was much larger than the value calculated from the potential gradient in the glass and the resistivity of the glass given in the text-books. Why so large a current is

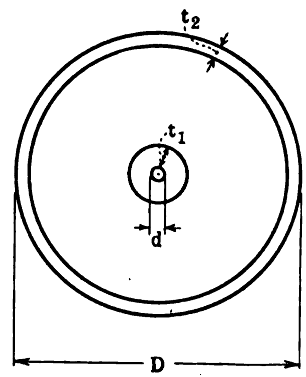

Fig. 24a

d = 3.96 mm.
t_1 = 1.33 mm.
t_2 = 1.75 mm.
D = 26.06 mm.

permitted to flow through the glass and enables electrical precipitation with glass-covered electrodes is the most important and interesting problem regarding their treater.

On this question the authors made the following experiments.

a. Variation of Resistivity of Glass with Temperature. In order to determine the effect of temperature upon the resistivity the following experiment was made in the Electrotechnical Laboratory, Tokyo. The connection is shown in Fig. 25. T is the high-voltage transformer; K, the kenotron with which high-voltage alternating current is rectified; A_m, sensitive d-c. millivoltmeter of permanent magnet type; G, the glass tube the resistivity of which was to be measured. One end of the glass tube was fused and the tube was filled with mercury and tin foils were stuck to the outer surface of the tube at the middle part of the whole length. The mercury and the tin foils were used as the electrodes. The tube was put into an oil bath and the temperature of the bath was gradually

changed, keeping the voltage constant; and the corresponding current through the glass tube was measured.

The tube tested was ordinary soda glass commonly used in chemical laboratories such as for the inlet pipe of wash bottles.

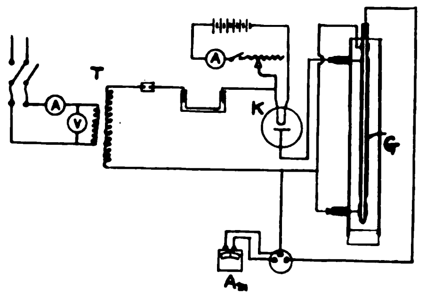

Fig. 25

The dimensions of the tube are shown below:

inner radius r_1.......	=	0.220	cm.
outer radius r_2.......	=	0.311	"
thickness t...........	=	0.091	"
length of tube.......	=	105	"
length of foil covering	=	65	"

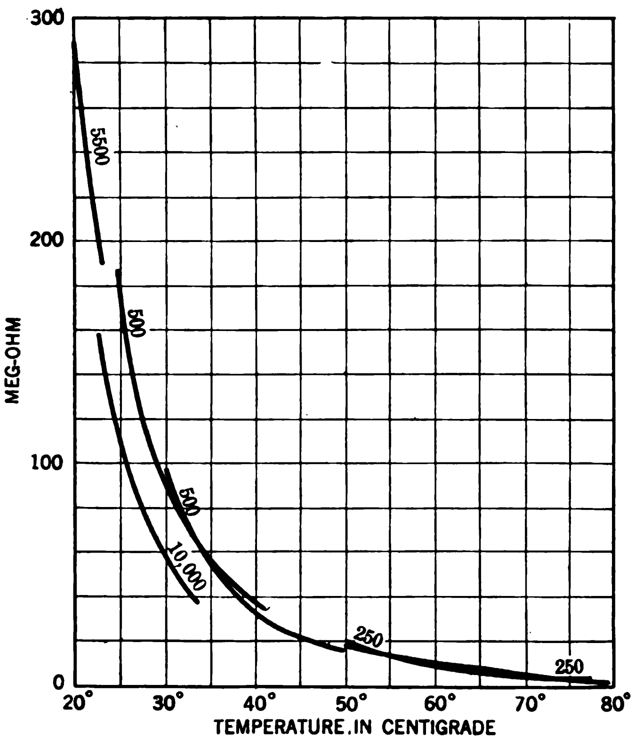

Fig. 26

As the guard ring prevents surface leakage, the millivoltmeter indicates the current through the glass only. Fig. 26 shows the results of several experiments. Here, as the ordinates, the apparent resistance of the tube (ratio of voltmeter readings to the readings of ammeter A_m multiplied by transformer ratio) and as the abscissas, the temperature in degrees centigrade were taken. As may be seen from the figure, the curves for 500 and 250 volts are nearly coincident, while curves for 5500 volts and 10,000 volts are respectively under the above curve although they have the character of a similar nature. The logarithmic values are plotted in Fig. 27, which lie nearly on respective straight lines.

The reading of the voltmeter denotes the effective value of the electromotive force, *i. e.* $\frac{1}{\sqrt{2}}$ of the

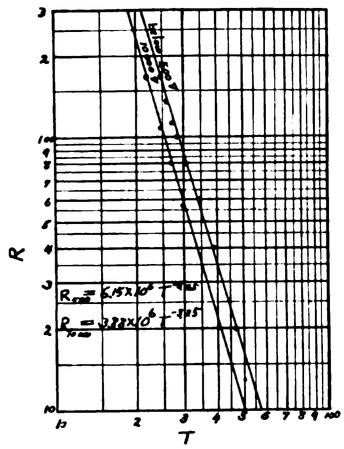

Fig. 27

maximum value, and the reading of the permanent magnet d-c. millivoltmeter, is the mean value of the half wave taken on the whole period and equal to $\frac{1}{\pi}$ of the maximum value. Taking this into ac-

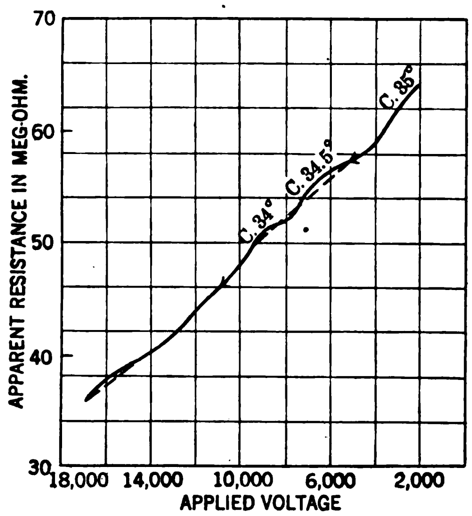

Fig. 28—"B" Glass Tube in Oil Bath—Applied Voltage-Resistance Curve

count and with the aid of Fig. 27, and the formula

$$R = \frac{\rho}{2\,\pi\,l}\log_e\frac{r_2}{r_1}$$, we get the resistivity as follows:

$$\rho = \frac{3.28 \times 10^9}{T^{3.25}}$$

(for applied voltage below 500 and temperatures between 25 deg. cent. and 80 deg. cent.)

$$\rho = \frac{2.06 \times 10^9}{T^{3.25}}$$

(for applied voltage 10,000 and temperatures between 20 deg. cent.) and where ρ is resistivity in megohm-cm. and T temperature in degrees centigrade.

b. Variation of Resistivity of Glass with Potential Gradient. In order to determine the effect of the potential gradient on the resistivity of glass, the authors made the following experiments.

The apparatus used and the connections were the same as the experiment for (a). The applied voltage was gradually changed and the millivoltmeter reading as well as the temperature of the oil bath was taken. Fig. 28 is the resistivity-potential curve for the same glass tube as in the experiment (a). Here the abscissas are the primary voltage multiplied by the transformer

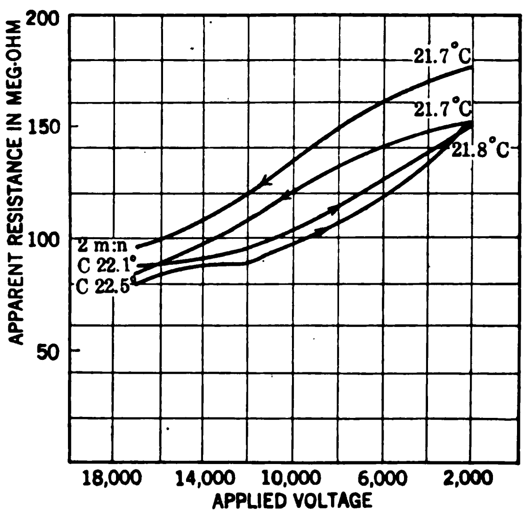

FIG. 29—"D" GLASS TUBE IN OIL—APPLIED VOLTAGE-RESISTANCE CURVE

ratio and the ordinates are the apparent resistance ratio of the readings of voltmeter (V) to that of the ammeter (Am) times transformer ratio. The potential gradient in the tube is not uniform and is given by

$$G_x = \frac{e}{x \log_e \dfrac{R}{r}}$$

while the mean value is

$$G_{mean} = \frac{1}{R - r} \int_r^R \frac{e\,dx}{x \log_e \dfrac{R}{r}} = \frac{e}{R - r} .$$

Therefore the potential gradient at the inner and outer sides of the tube at the mean potential gradient for 1000 applied volts is as follows:

$$G_{outer} = \frac{1000}{0.311 \log_e \dfrac{0.311}{0.220}} = 9307 \text{ volts per cm.}$$

$$G_{inner} = \frac{1000}{0.220 \log_e \dfrac{0.311}{0.220}} = 13{,}160 \text{ volts per cm.}$$

$$G_{mean} = \frac{1000}{0.311 - 0.220} = 11{,}000 \text{ volts per cm.}$$

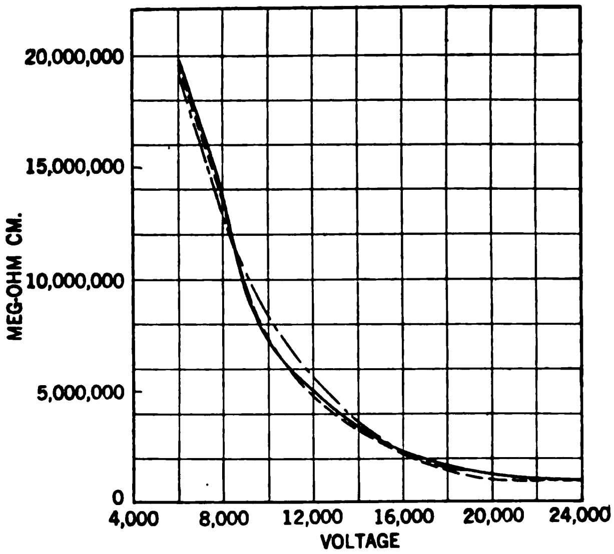

FIG. 30—"JENA" GLASS TUBE—APPLIED VOLTAGE AND SPECIFIC RESISTANCE CURVE

inner diameter 0.1128 cm.
outer diameter 1.0000 "
thickness 0.4432 "
effective length 34.0000 "

Fig. 29 shows the curve for another glass tube.

As may be seen from the curves the values of resistivity in the increasing voltage are higher than those in decreasing voltage, which may be the effect of the

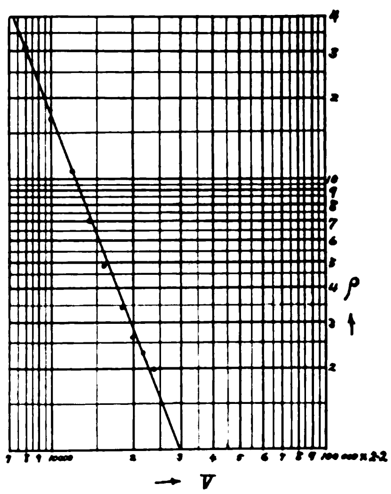

FIG. 31

temperature. Therefore the decrease of resistivity with the potential gradient may be partly due to the increase of the internal temperature.

Thus whether the decrease of resistivity of glass with the potential gradient is the direct effect of potential gradient or indirect effect of the heat in the glass due

to the ohmic loss is now in question, but for our purpose, it is sufficient to know that the resistivity of glass decreases with the potential gradient; the reason will be left for further study.

Fig. 30 shows the results of the same experiments with the Jena glass, which is to be used for the resistance standard.

The dimensions of the tube are

inner diameter.....................0.1128 cm.
outer diameter.....................1.000 "
thickness.........................0.4436 "
length of tin-foil covering......34.00 "

With the same circuit diagram as Fig. 27 the relation between the resistivity and the applied voltage was measured. In this experiment the oil bath was not used and the measurement was made at room temperature, 17 deg. cent.

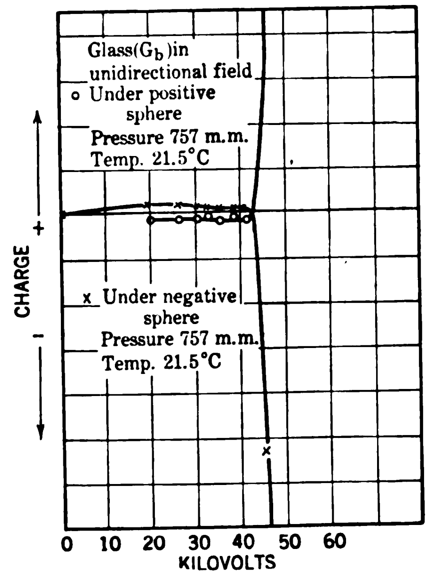

FIG. 32A

The voltage was gradually increased and then decreased, and this was repeated for several cycles. The results are represented by a curve as shown in Fig. 30, which does not show a hysteresis as in Fig. 29, which may be attributed to the superior quality of the Jena glass.

The resistance and the applied voltage have a logarithmic relation to each other as seen in Fig. 31, from which we may derive the relation between resistivity and the applied voltage in the same manner as in the calculation of resistivity from Fig. 27. Thus

$$\rho = 2.9 \times 10^9 \, V^{-2.60} \quad (V \text{ in kv.})$$

The potential gradient at the inner and outer sides of the tube and the mean potential gradient for applied voltage of 1000 are:

$$G_{inner} = \frac{1000}{0.1128 \log_e \dfrac{1.000}{0.1128}} = 4064 \text{ volts per cm.}$$

$$G_{outer} = \frac{1000}{1.000 \log_e \dfrac{1.000}{0.1128}} = 465 \text{ volts per cm.}$$

$$G_{mean} = \frac{1000}{1.000 - 0.1128} = 1130 \text{ volts per cm.}$$

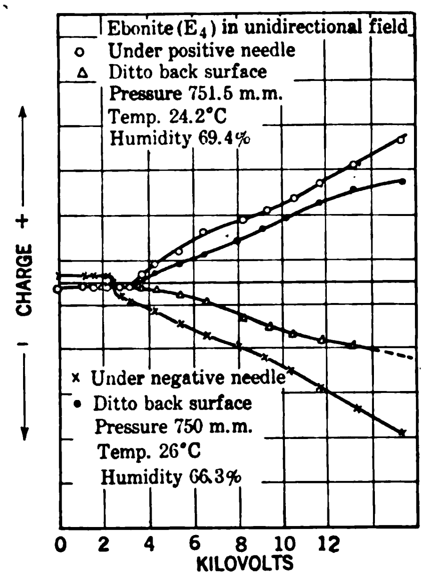

FIG. 32B

Using the mean potential gradient (G_m) as parameter, the resistivity may be expressed as

$$\rho = 4.0 \times 10^9 \, G_m^{-2.60}$$

where ρ is the resistivity in megohm-cm. and G_m is the potential gradient in kv. per cm. for the range between $G_m = 7$ and 27.

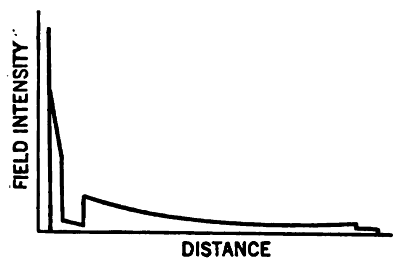

FIG. 33

c. Free Charges on the Glass Surface. Mr. Nishi, Assistant Professor at the Imperial University of Tokyo, published a part of his research on dielectrics in the *Journal of Electrical Society of Japan*, February, 1920. He found that the definite free charge appears always on the surface of the dielectrics, placed in an electric field, after the field is removed. Fig. 32 shows the curves for glass and for ebonite, taken from his paper. The glass or ebonite plates were placed between sphere or needle and plate electrodes, and at a given potential difference between electrodes the free charge appearing on the surface of the dielectric was measured with a sensitive ballistic galvanometer

or quadrant electrometer after the potential was removed. In unidirectional field, free charge of the polarity opposite to that of the electrode appears on the surface below a certain limit of potential difference, above which the sign of the polarity changes. Taking these experimental results as basis Mr. Nishi derived a theory for the authors' precipitation treater as follows:

Take, for instance, the treater, the section of which, is shown in Fig. 1. Fig. 33 shows the potential gradient curve of it calculated statically. Assume the active electrode be taken as negative, then the negative charge will appear on the inside surface of inner glass covering and the positive charge on its outside surface, and the negative charge on the inside surface of outer glass covering. As the results of these charges, the potential gradients in the glass will be much higher than the value calculated statically and the gradient in the air will be decreased by the appearance of free charges on the dielectrics. The supposed potential gradient curve may be shown as in Fig. 34 instead of Fig. 33. This high-potential gradient in the glass combined with the diminution of resistivity of glass with temperature and potential gradient will be sufficient to permit an unexpectedly by large current to flow through the glass.

d. Numerical Calculation on the Treater used in Oscillographic Study. In the oscillographic study we get 0.2 milliampere of the current through the treater, the section of which is shown in Fig. 1, by applying 26,000 volts. (cf. Fig. 2.)

Now taking the resistivity of glass obtained by the two experiments above mentioned, we will calculate the potential difference at the two surfaces of inner glass covering and those of outer glass covering, in order to cause the passage of 0.2 milliampere of current.

The resistances of inner and outer glass coverings are

$$R_{inner} = \frac{\rho}{2\pi l} X \log_e \frac{r_3}{r_2} = \frac{\rho}{2\pi \times 120} \log_e \frac{2}{1}$$

$$= 0.92 \times \rho \times 10^{-3}$$

$$R_{outer} = \frac{\rho}{2\pi l} \log_e \frac{r_5}{r^4} = \frac{\rho}{2\pi \times 120}$$

$$\times \log_e \frac{15}{14} = 0.90 \times \rho \times 10^{-4}$$

Taking the resistivity of glass at

$$\rho = \frac{2.06 \times 10^9}{T^{3.25}}$$

and assuming the temperature at 30 deg. cent we get

$$R_{inner} = 0.92 \times 10^{-3} \times \frac{2.06 \times 10^9}{(30)^{3.25}}$$

$$= 28.9 \text{ megohm.}$$

$$R_{outer} = 0.90 \times 10^{-4} \times \frac{2.06 \times 10^9}{(30)^{3.25}}$$

$$= 2.8 \text{ megohm.}$$

Therefore in order to cause 0.2 milliampere of current to pass the potential differences must be

$$V_{inner} = 5780 \text{ volts.}$$

$$V_{outer} = 567 \text{ "}$$

The authors are of the opinion that the pure statical treatment on the electrical precipitation treater must

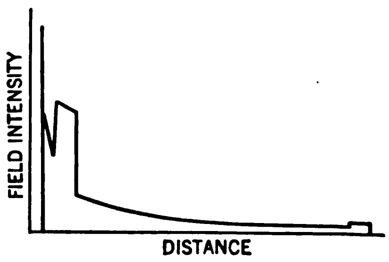

Fig. 34

have very little value but in order to give a rough idea, these values will be compared to the calculated values assuming the treater as a pure cylindrical condenser.

The potential gradient in the treater, when considered as a cylindrical condenser, is given by the formula;

$$G = \frac{E}{X K \left[\log_e \frac{r_2}{r_1} + \frac{1}{K} \log_e \frac{r_3}{r_2} + \log_e \frac{r_4}{r_3} + \frac{L}{K} \times \log_e \frac{r_5}{r_4} \right]}$$

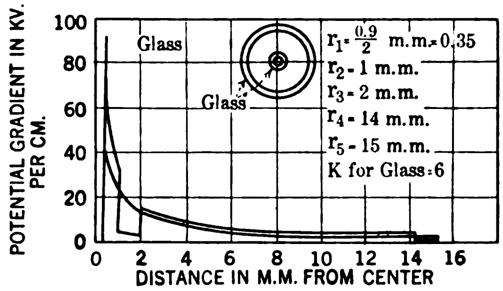

Fig. 35

and is shown in Fig. 35 for the applied voltage of 10,000. The potential differences at two surfaces at inner and outer glass covering where 26,000 volts are applied between two electrodes are as follows:

$$V_{inner} = \int_{r2}^{r3} g_x \, dx = 960 \text{ volts}$$

$$V_{outer} = \int_{r4}^{r5} g_x \, dx = 93 \text{ volts}$$

These values are nearly one-sixth of the values, necessary to cause 0.2 milliampere to pass; the difference may be due to the effect of the free charge on the glass surface and the existence of charged particles

in the space of the treater etc. As shown in the above paragraph, the actual potential gradient in the glass will be much higher than the value calculated statically; but, unfortunately the amount of this increase cannot be calculated quantitatively, still, the authors believe that the increase of the potential gradient to the value a few times the statically calculated one is possible and the current found in the laboratory experiment will be easily allowed to pass through the glass.

e. Conclusions. As to the reason why so large a current is permitted to flow through the glass and enables electrical precipitation with glass-covered electrodes, the authors conclude as follows:

(1) Resistivity of glass decreases with temperature as well as with potential gradient applied.

(2) Free charge appears on the surface of the glass placed in the electric field, which causes, in the dielectrics, a potential gradient much higher than that calculated by mere statical consideration.

(3) As the current necessary for the electrical precipitation is very small, the above mentioned two causes permit a sufficient current to enable electrical precipitation to flow through the dielectrics.

A Simple Harmonic Analyser

BY V. BUSH.

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THIS paper describes a new mechanical integrator which it is hoped will fill a need, particularly among electrical engineers, for a simple inexpensive device of this nature.

It will evaluate the integral

$$\int f(x) \sin(\omega x + \beta)\, d x$$

where $f(x)$ is any known single valued function. Thus its principal use will be the determination of the harmonics of an irregular function, such as the problem of splitting an oscillograph curve of current or voltage into its components. It may be useful also in other connections in which the above integral occurs, as for instance in Carson's extension of Heaviside's expansion theorem for determining the alternating from the constant potential solution of transients in a network.*

Schedule methods of harmonic analysis are usually laborious and often not highly accurate, particularly where a single high harmonic is desired. There are many forms of mechanical integrators for this purpose, some of which are excellent, but they are usually too expensive for the small engineering office or laboratory. Chubb's polar form is particularly useful in connection with a polar ocsillograph, but it is inconvenient in other connections, and quite complicated. The Coradi analyser is probably the most convenient machine, since it works in rectangular coordinates and determines several components simultaneously. Very few of these instruments are in use, however, because of their cost. The present instrument is quite similar in theory to several forms which have been proposed, but it has been simplified mechanically.

The analyser consists of a set of transparent disks, preferably of celluloid, a planimeter of any convenient form, and a piece of silk fish line. The disks are prepared as shown in Fig. 1. The edge is grooved to a diameter d, or more exactly to a diameter less than this chosen value by the thickness of the line used. The upper surface carries two depressions, A and B, connected by a straight trough. A is at the center of the disk, and B preferably at a radius $d/2$, although B may be placed elsewhere if desired and correction made by a constant factor. In the center of the bottom surface of the disk is a dot. The disk is graduated in angles, clockwise from the trough, the marks being preferably on the lower surface.

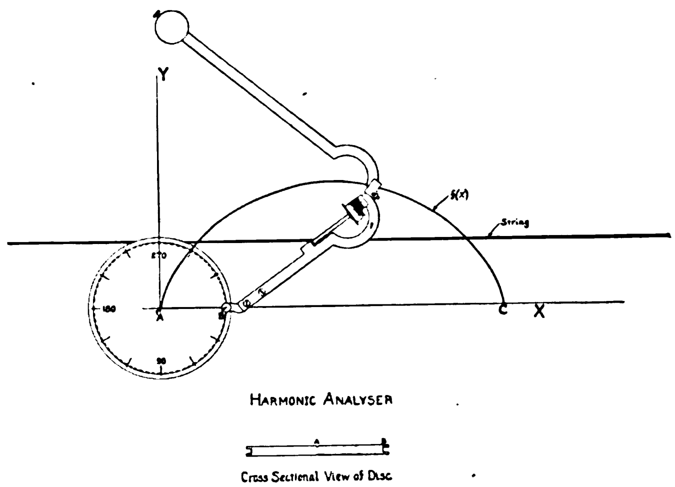

FIG. 1

The instrument is set up for use as follows. The curve to be analysed is plotted to a convenient scale in rectangular coordinates, and placed in the center of a long table. A disk of size corresponding to the desired component is placed on this plot. The length of a complete period of the plot divided by πd will give the order of the harmonic which will be obtained. In other words, if a disk of diameter d is to be used, and the nth harmonic is desired, a scale for the plot

*John R. Carson, PROC. A. I. E. E, March, 1919.

should be chosen such that a period of the curve covers a distance $\pi d n$. The line is then given a single turn clockwise about the disk, fastened to the ends of the table and pulled fairly taut. The plot is now fastened down with the horizontal axis parallel to the line. This set up is shown in Fig. 1 and Fig. 2. By placing a sharp point in A, the disk may now easily be moved over the plot. When moved vertically it will not rotate; but when moved horizontally it will turn through an angle proportional to the distance moved. The disk may be moved over an ordinate near each end of the plot, and the constancy of the angular scale reading of the ordinate noted to check the alignment; and the scale of the plot may be checked by moving the disk horizontally over a period and noting that it makes the correct number of revolutions. Of course, as with any such integrator, symmetry may be made use of and a plot of one-half, or even one-quarter of a period of the curve utilized.

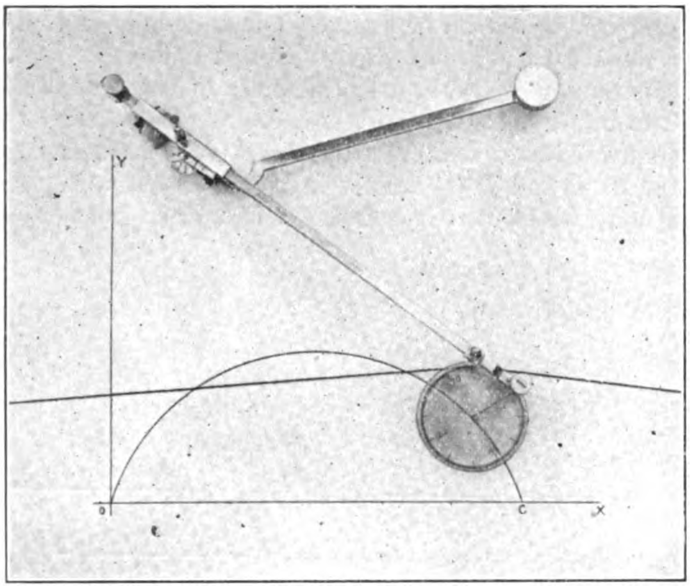

Fig. 2

The disk is now placed with its center at the origin of the curve, and the trough making an angle β with the horizontal axis. If β is zero, a sine component will be obtained; if 90 deg., a cosine component, etc. The planimeter point is placed in depression B, and the planimeter scale set at zero. By placing a sharp point in A, the center of the disk is now made to traverse the path out along the horizontal axis and back along the curve to the origin. To the reading of the planimeter is now added the area under the curve. The result divided by half the length of the base of the curve gives the ordinate of the desired component in terms of the constant of the planimeter. Thus if the planimeter reads in square inches, the final area reading is to be multiplied by two, divided by the base of the curve in inches, and the ordinate will be in inches. This value may then be interpreted in terms of the scale of the curve.

If a complete period of a symmetrical curve is used, the net area under the curve will be zero and the first planimeter reading divided by the half period gives the desired ordinate directly. In other cases the area to be added may be determined by running the planimeter point over the curve in a positive direction.

If several components are desired, they may be determined by separate disks, or all components may be found with the same disk by plotting to different scales. This latter procedure is of course less convenient. A table of disk sizes, scales and order of components is shown in Note 1 for convenience. A rolling planimeter will be found most convenient, although the polar form will do.

The theory of operation is given in appended Note 2. This derivation is not new but is placed here for convenience of those wishing to extend the application of the device to other problems.

The accuracy of the device appears to be limited by the accuracy with which the point may be caused

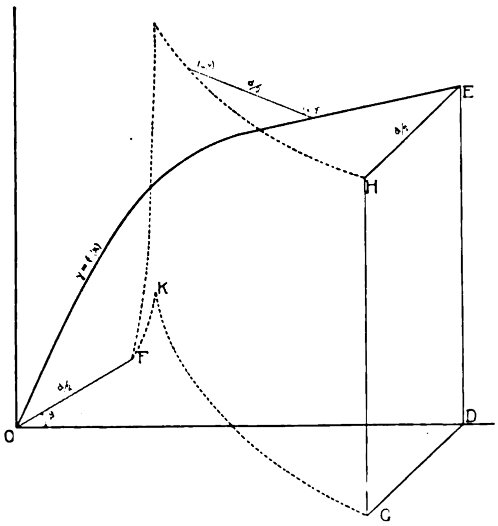

Fig. 3

to trace the curve, that is by the accuracy of the planimeter. Tests on curves of which the components could be formally computed have shown that results obtained may be depended upon to usual planimeter accuracy. The precision is hence greater than that of the oscillograph with which the harmonic analyser is often used, and compares very favorably with that of other mechanical and graphical methods.

In view of the present wide use of the oscillograph and the frequent necessity for curve analysis in other engineering work, it is believed that the above device will be found useful.

NOTE 1.

Table of Order of Harmonics

A set of disks which has been found useful is shown in Fig. 4. There are 20 disks in the set, marked with the length of the base covering one cycle and the

harmonic which will be obtained. Thus 24-1 indicates a disk which will obtain the fundamental when used on a curve plotted so that one cycle is 24 inches in length. The following table indicates harmonics which can be obtained by the use of various ones of these disks. Other combinations are easily obtained.

LENGTH OF ONE CYCLE

Harmonic	48	36	32	24	16	12	8
							24-3
1				24-1	16-1	12-1	8-1
2	24-1		16-1	12-1	8-1		
3	16-1	12-1		24-3	16-3	12-3	8-3
4	12-1		8-1				
5				24-5	16-5	12-5	8-5
6	8-1		16-3	12-3	8-3		
7	24-3			24-7	16-7	12-7	
8							
9	16-3	12-3		24-9	16-9	12-9	
10	24-5		16-5	12-5	8-5		
11				24-11	16-11		
12	12-3		8-3				
13				24-13	16-13		
14	24-7		16-7	12-7			
15	16-5	12-5		24-15			
16							
17							
18	8-3		16-9	12-9			
19							
20	12-5		8-5				
21	16-7	12-7					
22	24-11		16-11				
23							
24							
25							
26	24-13		16-13				
27	16-9	12-9					

NOTE 2.

Theory of Operation

The amplitude of the nth harmonic of a periodic curve $y = f(x)$ is given by:

$$\frac{1}{c}\int_{-c}^{c} f(x)\sin\left(\frac{\pi n x}{c} + \beta\right) d x$$

where $2c$ is the period.

Abbreviating by:

$$\omega = \frac{\pi n}{c}$$

the integral

$$\int f(x)\sin(\omega x + \beta)\, d x$$

is to be evaluated and divided by c in order to give the ordinate of the nth harmonic, where β is the phase angle of the desired component.

Referring to Fig. 3, when the center of the disk traces the path $O\,D\,E\,O$, the planimeter point will trace the path $F\,K\,G\,H\,F$. When the center is at (x, y), the planimeter point will be at (u, v) where

$$u = x + \frac{d}{2}\cos\left(\frac{2x}{d} + \beta\right)$$

$$v = y + \frac{d}{2}\sin\left(\frac{2x}{d} + \beta\right)$$

The area swept out by the planimeter will be:

$$\int v\, d u$$

taken over the boundary $F\,K\,G\,H\,F$.

Along the path $F\,K\,G$ we have $y = 0$ and the total area is hence:

$$A = \int\left[\frac{d}{2}\sin\left(\frac{2x}{d} + \beta\right)\left\{d x - \sin\left(\frac{2x}{d} + \beta\right) d x\right\}\right] - \int\left\{y + \frac{d}{2}\sin\left(\frac{2x}{d} + \beta\right)\right\}\left\{d x - \sin\left(\frac{2x}{d} + \beta\right) d x\right\}$$

or:

$$A = -\int y\, d x + \int y \sin\left(\frac{2x}{d} + \beta\right) d x$$

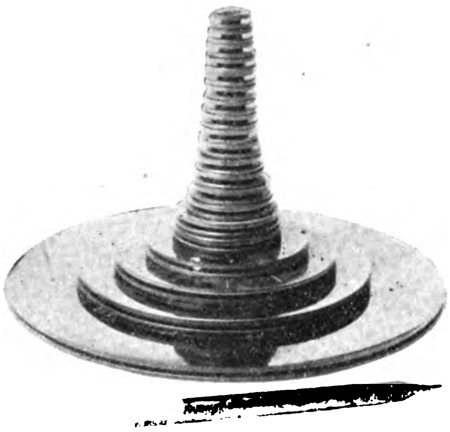

Fig. 4

This will be the value of the planimeter reading.

If we add to this the area under the curve, and set

$$\frac{2}{d} = \omega$$

our result will be:

$$\int y\sin(\omega x + \beta)\, d x$$

or the desired integral.

Thus if the diameter of the disk is chosen with respect to the period of the curve $2c$, in such a manner that

$$\pi d = \frac{2c}{n},$$

the planimeter reading plus the curve area divided by c will give the ordinate of the nth harmonic.

Induction Motor Core Losses*

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AND

R. EKSERGIAN

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An analysis of the core losses in induction motors is the object of the research described in this paper. The authors subdivide the core losses into six elements and point out that only one of the six is ordinarily calculated by designing engineers, with resulting large discrepancies between expectation and fact. The belief is expressed that to calculate other elements approximately is entirely feasible and that such calculations would explain most of the variations in core loss now attributed to imperfections in manufacture.

Rational formulas are developed for the losses in the core back of the teeth, which are found to give larger values than the more approximate formulas now in use, and the conclusions are presented in the form of charts giving the correction factors to apply to the usual formulas for all ordinary conditions.

A Webb floating dynamometer, which was constructed for the measurement of the extremely small torques due to these core losses, is described: and results on the losses in a smooth-core rotor obtained with it are presented. These results and those obtained by an independent electrical method of testing are compared with the expected values based on the theoretical conclusions previously derived, reasonable agreement being found.

Introduction

THIS paper describes certain results of a research directed to improving the precision of computing iron losses in induction motors. The research was carried on by Mr. A. A. Prior and by the authors for the period of a year each during 1914-1917, under the direction of Prof. C. A. Adams, and with the aid of a research appropriation from the American Telephone & Telegraph Co., under the then existing joint cooperative arrangement of Harvard University and the Massachusetts Institute of Technology. The experiments were carried on in the laboratories of both these institutions. After two years of interruption, due to the War, the analysis and collation of the results have been taken up by the authors during the fall of 1919.

It is now the practise of designers to base their estimates of the core losses in projected machines upon previous experience with similar machines, using as criteria of similarity the frequency, the flux densities in core and teeth, and a few general features of design. Actually, the core losses depend upon many of the elements of design. Large discrepancies between the estimated and observed iron losses of new machines are therefore of frequent occurrence, and an entire re-design is sometimes necessitated.

An improved knowledge of the nature and causes of iron losses is evidently very desirable. The ability to predict the core loss more accurately will enable factors of safety in design to be reduced, materials to be more economically utilized, and an intelligent choice between possible alternatives to be made. Until the phenomena of core losses are thoroughly understood it cannot be said that radical reductions may not be made in the losses at present tolerated.

Even if it were true, as is often thought, that the core losses in similar machines varied widely due to slight accidental variations in manufacture, an understanding of the nature and causes of the loss would be exceedingly desirable; since an accidental occurrence is essentially avoidable and such a knowledge would lead to the prevention of the avoidable causes of loss. A careful comparative test recently made of six motors of each of two types shows, however, that the core losses in similar motors made in large scale production do not differ greatly. More than usual care was taken in assembling these motors, and accidental variations were avoided, and the test results must be considered as indicative of better than average conditions. The core losses of the two groups were determined to be as follows:

WATTS CORE LOSS AT 60 CYCLES.

	Group 1.			Group 2.		
	Max.	Min.	Av.	Max.	Min.	Av.
At 250 Volts	340	300	319	335	270	317
At 350 Volts	570	505	550	565	515	544
At 440 Volts	905	820	871	870	790	837
At 550 Volts	1375	1280	1332	1340	1175	1275

These tests give a mean variation of only 3 per cent in core loss between supposedly identical motors.

The problem of predetermination of core losses is of long recognized importance, but as yet the consensus of published opinion is in favor of entirely empirical methods in its treatment. This research was inspired by the belief that a rational and comprehensive investigation of the problem must give the ability to predict with reasonable accuracy the iron losses in any machine.

To be presented at the Pittsburgh Section Meeting, October 12, 1920.

*The continuation on a more comprehensive scale of the research, the early stages of which are discussed in this paper, will be conducted under the auspices of the Division of Engineering of the National Research Council and under the direction of a committee of which Dr. A. E. Kennelly is chairman. One branch of this research is now under way at the Electrical Engineering Laboratory of the Harvard Engineering School.

The method of research outlined was to divide the recognized causes of core loss into reasonably distinct elements which are capable of independent variation and to carry out a series of quantitative tests in which each element was varied over as wide a range as possible. In this way a separation of the elements may be experimentally performed, and comparing the observed character of each loss with expectations based on the theoretical grounds should enable a rational formula to be developed for each element.

For the purposes of study, the iron losses occurring in polyphase induction machines may be analyzed into the following elements:

1. Legitimate losses due to fundamental flux wave.
   a. In the cores.
   b. In the teeth.
2. Fundamental frequency losses due to the leakage fluxes.
   a. Slot leakage flux losses.
   b. Losses in metal wedges.
3. Tooth frequency losses due to permeance variations in the main magnetic circuit.
   a. In the teeth.
   b. In the cores.
4. Tooth frequency losses due to leakage fluxes.
   a. Tooth tip or zigzag flux losses.
5. Pole face or wave losses in the tooth tips.
6. Losses due to nonsinusoidal current distribution.
   a. Losses due to spreading of the main flux in the cores just back of the teeth.
   b. Losses due to harmonics other than tooth harmonics.
7. Illegitimate core losses due to imperfections of manufacture.

Each type of loss occurs in both rotor and stator. Each element may be subdivided into a hysteresis and an eddy current portion; 1 and 3 may be expected to decrease slightly when the machine is put under load, while the others may be expected to increase under load. The latter elements therefore are possible sources of load losses. In addition to these true iron losses there are usually copper losses of appreciable amount which are included in the core loss as ordinarily measured.

These copper losses may arise from the short-circuiting in the rotor of voltages induced by the tooth frequency flux pulsations. Squirrel-cage motors are particularly likely to have losses of this kind owing to the low-resistance paths offered to circulating currents. Another important source of copper losses which are often assumed as core losses exists in the belt leakage fluxes or winding harmonics, which also induce high-frequency circulating currents in the rotor. A third type of extra copper loss is the eddy loss in the copper produced by the slot leakage fluxes. All these types of loss increase with load and form important sources of load loss.

This research is limited to a study of the legitimate no-load core losses. The illegitimate losses of type 7, and the load losses form separate fields of investigation which will not be further touched upon here. It should be emphasized, however, that such losses as these of the types described in the preceding paragraph, which are perfectly subject to predetermination, and yet which are usually neglected, probably form an important source of those discrepancies between expectation and fact that have kept the subject on an empirical basis for so long.

In choosing the element of the true core loss to be first investigated, the qualities of independent existence and fundamental character were sought. The losses of type 1 a, which occur in the core back of the teeth, were consequently selected as the most suitable for first investigation. The results of a study of this element of the loss form the principal subject of this paper. In the next few pages are given the theoretical results obtained and in the succeeding pages the experimental work is described and its results presented.

Iron Losses in the Core Proper

The distributed winding of a polyphase induction motor gives rise to a revolving train of flux waves which are in the usual analysis resolved into a fundamental sinusoidal train and a series of harmonic trains. The fundamental train revolves at a speed equal to $\frac{60 f}{P}$ revolutions per minute, where f is the frequency in cycles per second, and P is the number of pairs of poles. The nth harmonic has $2\,n\,P$ poles and revolves at one-nth the fundamental speed. If the winding were uniformly distributed and had an infinite number of phases, these harmonics would not exist. In practise they are usually small and may be treated independently of the fundamental. They cause losses of type 6 *b*.

The fundamental flux may then be considered as crossing the air gap in a radial direction at every point and as sinusoidally distributed in the gap both as regards time and space. A similar distribution may be assumed to exist at the gap periphery of the stator and rotor cores, if the alternate contractions and rarefactions due to the teeth, which cause losses of type 6 *a*, are neglected.

Rudenberg[1] has obtained expressions for the flux density at any point inside the core for this type of peripheral flux distribution, and his equations will therefore enable the core losses to be computed.

Let:	P	= No. of pairs of poles.	numeric
	θ	= Mechanical angular displacement of any point in core from the center line of a South Pole.	radians
	R	= Radius to any point in core.	cm.

1. *Elektrotechnische Zeitschrift*, 1906-p. 109.

R_a	=	Radius to periphery of core nearest air gap.	cm.
R_i	=	Radius to periphery of core furthest from air gap.	cm.
a	=	$R_a \div R_i$ ($a < 1$ for stator, $a > 1$ for rotor).	numeric
B_r	=	Radial component of flux density at any point in core.	gausses
B_θ	=	Tangential component of flux density at any point in core.	gausses
ϕ	=	Total flux per pole.	maxwells
L	=	Net core length.	cm.

Referring to Fig. 1, and considering an element of area $R\,d\,R\,d\,\theta$ at R, θ, we will apply the two fundamental laws of magnetic distribution. First, *the lines of induction are continuous*, or the total flux entering any area is equal to that leaving it. Expressed as an equation:

$$\frac{d\,B_\theta}{d\,\theta} + B_r + R\frac{d\,B_r}{d\,R} = 0 \tag{1}$$

(1) is true regardless of permeability variations.

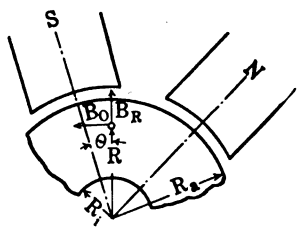


FIG. 1

Second, *the line integral of the m. m. f. around the area is zero*, since there are no currents flowing through the area in a direction perpendicular to its plane. Or,

$$\int H\,d\,l = \int \frac{B}{\mu}\,d\,l = 0$$

To make use of this equation, we will have to take the permeability to be constant (to avoid extreme mathematical complexity), when it becomes:

$$\int B\,d\,l = \frac{d\,B_r}{d\,\theta} - R\frac{d\,B_\theta}{d\,R} - B_\theta = 0 \tag{2}$$

Combining (1) and (2);

$$\frac{1}{R^2}\;\frac{d^2\,B}{d\,\theta^2} + \frac{d^2\,B}{d\,R^2} + \frac{3}{R}\;\frac{d\,B}{d\,R} + \frac{B}{R^2} = 0 \tag{3}$$

(3) is valid for both B_θ and B_r. Its general solution is:

$$B = (A\,R^{\alpha-1} + B\,R^{-\alpha-1})\sin\alpha\,(\theta - \theta_0) \tag{4}$$

To determine the constants, we have the boundary conditions:

When $R = R_a$;

$$B_r = \frac{R\,\phi}{2\,L\,R_a}\cos P\,\theta \tag{5}$$

and when $R = R_i$;

$$B_r = 0 \tag{6}$$

Substituting (5) and (6) in (4), (2), and (1), Rudenberg obtained:

$$B_r = \frac{P\,\phi}{2\,R\,L}\,(A\,R^P - B\,R^{-P})\cos P\,\theta$$

$$= \text{radial density} \tag{7}$$

$$B_\theta = \frac{P\,\phi}{2\,R\,L}\,(A\,R^P + B\,R^{-P})\sin P\,\theta$$

$$= \text{tangential density} \tag{8}$$

Where:

$$A = \frac{R_a^{P}}{R_a^{2P} - R_i^{2P}} = \frac{a^{2P}\,R_a^{-P}}{a^{2P} - 1} \tag{9}$$

$$B = \frac{R_a^{-P}}{R_i^{-2P} - R_a^{-2P}} = \frac{R_a^{P}}{a^{2P} - 1} \tag{10}$$

Equations (7), (8), (9), and (10) completely determine the flux distribution in the core. They apply equally well to the stator or the rotor, the value of a being less than 1 in the first case and greater than 1 in the latter case. The equations show that the flux vector at each point of the core describes an elliptical cycle. The resultant density at any point does not reach zero at any time during a cycle, except where $R = R_i$. Since the permeability depends on the resultant density, and not on B_r or B_θ alone, it is more nearly constant than if the flux were of an alternating character and passed through zero on every cycle. Consequently, the assumption of constant permeability is not so great a source of error as might at first appear.

The eddy current losses due to the radial and tangential flux variations may be calculated independently, since they are always mutually perpendicular in space and can have no interaction on each other. In other words, the eddy current loss due to an elliptic flux variation is equal to the sum of the losses that would be caused by independently acting fluxes of amplitudes equal respectively to the major and minor axes of the ellipse.

Let:

E	=	Normal eddy current loss in core iron at 50 cycles, 10,000 gausses maximum in watts per cu. cm., as determined by Epstein tests.
f	=	Frequency of flux variation in core, or:
$2\,\pi\,f\,t$	= $P\,\theta$ =	Angular distance of revolution in electrical radians, in t seconds.

Then the average eddy current loss occurring at any particular point of the core is:

$$W_1 = E\left(\frac{f}{50}\right)^2 (B_r^2\text{ max.} + B_\theta^2\text{ max.})\,10^{-8}$$

$$\text{watts per cu. cm.} \tag{11}$$

Substituting the values of B_r and B_θ max. from (7) and (8),

$$W_1 = 2\,E\left(\frac{f\,P\,\phi}{R\,L}\right)^2 (A^2 R^{2P} + B^2 R^{-2P})\,10^{-12} \quad \textbf{(12)}$$

The average eddy loss is independent of θ, because of the core's circular symmetry. By integrating (12) over the entire core the total eddy current loss will be obtained:

$$W = L \int_0^{2\pi} d\,\theta \int_{R_i}^{R_a} W_1\,R\,d\,R \quad \textbf{(13)}$$

The limits R_i and R_a should be interchanged when $R_i > R_a$, in the case of the stator core, or the negative sign that will otherwise be obtained should be dropped. Evaluating (13) by means of (12), there is found:

$$W = \frac{2\,\pi\,E\,P}{L}\,(f\,\phi)^2 \left(\frac{R_a^{2P} + R_i^{2P}}{R_a^{2P} - R_i^{2P}}\right) 10^{-12} \text{ watts} \quad \textbf{(14)}$$

Expressed in terms of the ratio of R_a to R_i, a, (14) becomes:

$$W = \frac{2\,\pi\,P\,E\,f^2}{L}\left(\frac{\phi}{10^6}\right)^2 \left(\frac{a^{2P}+1}{a^{2P}-1}\right) \text{watts} \quad \textbf{(15)}$$

or,

$$W = \frac{2\,\pi\,P\,E\,f^2}{L}\left(\frac{\phi}{10^6}\right)^2 \coth\,(P \log_e a) \text{ watts} \quad \textbf{(16)}$$

Equations (14), (15), and (16) express the total eddy current loss in an annular core of uniform permeability subjected to a radial sinusoidally distributed magnetomotive force upon its inner periphery ($a < 1$), or its outer periphery ($a > 1$).

The commonly used formula for this loss is derived by considering only the eddy loss due to the tangential flux, and assuming this flux to be uniformly distributed across the core depth. It is:

$$W' = \text{Volume} \times (\text{Flux Density})^2 \times \left(\frac{\text{Frequency}}{50}\right)^2 \times 10^{-8} \times E.$$

$$= [\pi\,(R_a^2 - R_i^2)\,L]\left[\frac{\phi}{2\,L\,(R_a - R_i)}\right]^2 \left(\frac{f}{50}\right)^2 E 10^{-8}$$

$$= \frac{\pi\,E\,f^2}{L}\left(\frac{\phi}{10^6}\right)^2 \left(\frac{a+1}{a-1}\right) \quad \textbf{(17)}$$

Hence, the usual formula, (17), gives lower values than the new formula, (16). The ratio of (16) to (17) is:

$$K_1 = \frac{W}{W'} = 2\,P\left(\frac{a-1}{a+1}\right)\left(\frac{a^{2P}+1}{a^{2P}-1}\right) \text{ numeric} \quad \textbf{(18)}$$

$$= 2\,P \tanh\,(1/2 \log_e a) \coth\,(P \log_e a)$$

K_1 is equal to 1 when $a = 1$, or for very shallow cores. Its values for different values of P and a are plotted in Fig. 2. For excessively deep cores it approaches the value $2\,P$.

A theoretical value for the total hysteresis loss in the core may be derived in a similar way. In this case, however, the effects of the two perpendicular components of the flux variation are not independent. In fact, the generally accepted hypothesis is that the hysteresis loss due to an elliptic flux variation is the same as that caused by an alternating field of amplitude equal to the major axis of the ellipse. This hypothesis is based on molecular considerations. It will be accepted here.

To simplify the process of integration over the core, the additional assumption will be made that the hysteresis loss varies as the square of the maximum flux density. The 1.6 power law is more accurate, at least for medium densities, but no exponential law fits all cases and the exponent 2 is sufficiently near the average value to be acceptable for the purposes of this paper.

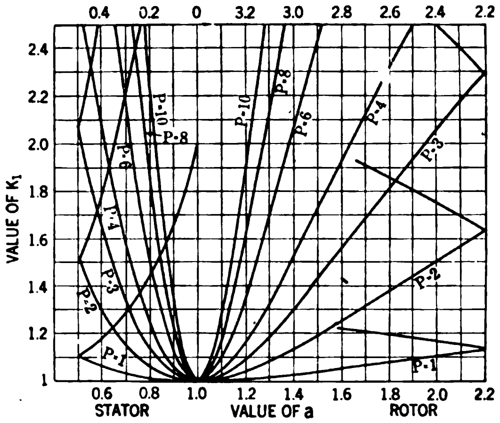


Fig. 2

On this basis, and since the major axis of the elliptic flux variation in the core is always tangentially directed, the specific hysteresis loss at any point of the core is:

$$V_1 = H\left(\frac{f}{50}\right)\left(\frac{B_\theta\,max.}{10^4}\right)^2 \text{watts per cu. cm., } \textbf{(19)}$$

where H is the hysteresis loss in watts per cu. cm. at 10,000 gausses, maximum, and 50 cycles, as determined by Epstein tests on samples of the core iron. B is given by (8).

Integrating (19) over the entire core,

$$V = \left(\frac{H\,f}{50\,L}\right) 10^{-8} \int_0^{2\pi} d\,\theta \int_{R_i}^{R_a} \frac{P^2\,\phi^2\,(A\,R^P + B\,R^{-P})^2}{4\,R}\,d\,R$$

$$= \frac{\pi\,H\,f\,P\,\phi^2\,10^{-10}}{2\,L}\left[\frac{a^P + a^{-P}}{a^P - a^{-P}} + \frac{4\,P}{(a^P - a^{-P})^2}\log_e a\right] \quad \textbf{(20)}$$

(20) may also be expressed as:—

$$V = \frac{\pi\,H\,f\,P\,\phi^2\,10^{-10}}{2\,L}\,[\coth\,(P \log_e a) + P \log_e a \operatorname{csch}^2 (P \log_e a)\,]$$

On the basis of the square law, the usual formula for hysteresis loss, which assumes uniform tangential flux density, is:

$$V' = \frac{\pi H f \phi^2 10^{-10}}{2L}\left(\frac{a+1}{a-1}\right) \tag{21}$$

$$= \frac{\pi H f \phi^2 10^{-10}}{2L} \coth\,(1/2 \log_e a)$$

Hence the ratio of the hysteresis loss with uniform permeability to that with uniform tangential flux distribution is:

$$K_2 = \frac{V}{V'} = P\left(\frac{a-1}{a+1}\right)$$

$$\left[\frac{a^P + a^{-P}}{a^P - a^{-P}} + \frac{4P}{(a^P - a^{-P})^2}\log_e a\right] \quad \text{numeric} \tag{22}$$

$$= P \tanh\,(1/2 \log_e a)\,[\coth\,(P \log_e a) + P \log_e a \operatorname{csch}^2 (P \log_e a)\,]$$

K_2 is plotted as a function of a and P in Fig. 3. Its value approaches unity for very shallow cores, while for very deep cores it apprcaches the limit P.

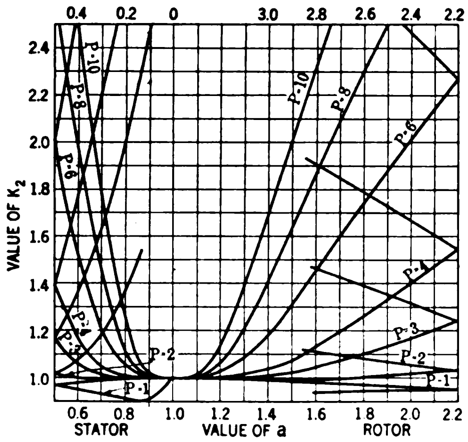


FIG. 3

In the case of a deep rotor core of uniform permeability and a small number of poles, the flux takes a nearly straight path from pole to pole, and hence the increased specific loss caused by the non-uniform distribution of flux is more than offset by the fact that the higher densities occur in the inner half of the core, and hence in a smaller volume of iron. This explains the existence of values of K_2 below 1.

Another interesting ratio which may be derived from these equations is the ratio of the m.m.fs. required to force the flux through the core under the two assumptions of uniform permeability and uniform tangential density. The core ampere turns per pole are equal to $1/2 \int H\,d\,l$ along any path between two adjacent pole centers. Choosing, for convenience, the path along the core periphery nearest the air gap, we have from (**8**), (**9**), and (**10**), when $R = R_a$:

$$B_\theta = \frac{P\phi}{2 L R_a}\left(\frac{a^P + a^{-P}}{a^P - a^{-P}}\right)\sin P\,\theta \tag{23}$$

Since B_θ varies sinusoidally with θ, its average value over the half pole pitch is $\frac{2}{\pi}$ times its maximum value. The length of path is $\frac{\pi R_a}{2P}$, so that the ampere turns per pole are:

$$N\,i = \int \frac{B}{\mu}\,d\,l$$

$$= \frac{P\phi}{2\mu L R_a}\left(\frac{a^P + a^{-P}}{a^P - a^{-P}}\right)\left(\frac{2}{\pi}\right)\left(\frac{\pi R_a}{2P}\right)$$

$$= \frac{\phi}{2\mu L}\left(\frac{a^P + a^{-P}}{a^P - a^{-P}}\right)$$

$$= \frac{\phi}{2\mu L}\coth\,(P \log_e a) \tag{24}$$

The usual formula, based on the assumption of a uniformly distributed flux across the core depth, is:

$$N\,i' = \frac{2}{\pi}\left(\frac{\text{max. flux density}}{\mu}\right)(1/2 \text{ mean pole pitch})$$

$$= \frac{2}{\pi\mu}\left(\frac{\phi}{2L(R_a - R_i)}\right)\frac{\pi (R_a + R_i)}{4P}$$

$$= \frac{\phi\,(a+1)}{4\mu P L\,(a-1)}$$

$$= \frac{\phi}{4\mu P L}\coth\,(1/2 \log_e a) \tag{25}$$

Hence the ratio of the constant permeability value to the usually taken value of the core ampere turns is:

$$K_3 = \frac{N\,i}{N\,i'} = \frac{2P\,(a-1)\,(a^P + a^{-P})}{(a+1)\,(a^P - a^{-P})} \quad \text{numeric} \tag{26}$$

$$= 2P \tanh\,(1/2 \log_e a)\coth\,(P \log_e a)$$

Equation (**26**) is identical with (**18**) so that $K_3 = K_1$ and the variations between the two formulas for core ampere turns are the same as those between the two formulas for eddy current loss and both are represented by Fig. 2.

It will be noted that formula (**24**) is exact if the permeability is constant and it therefore furnishes a useful means of computing the external reactance of the stator of an induction motor with rotor removed, or vice versa. In such a case, a equals eithe ,
and (**24**) reduces to the very simple form:

$$Ni = \frac{\phi}{2 \mu L} \text{ ampere turns per pole} \quad (27)$$

(For air, $\mu = \frac{4\pi}{10}$ if L is taken in cm.)

Reviewing the theoretical conclusions reached, formulas (**16**), (**20**), and (**24**), respectively express the total eddy loss, the total hysteresis loss, and the m. m. f. per pole existing in a laminated cylindrical core without teeth and of uniform permeability, when the core is subjected to a radial sinusoidally distributed flux on one of its cylindrical surfaces. The assumption of constant permeability makes the calculated eddy current loss too small as it neglects the extra losses produced by the harmonics which always accompany variations in μ.[2] The assumption makes the hysteresis loss too large, as saturation tends to equalize the density across the core.

Leaving out of consideration the extra losses due to the concentrations of flux behind the teeth, which should be treated separately, the formula for the eddy loss gives too small results and that for the hysteresis too large results.

The Supply of Losses

It is impossible to produce a single element of the core loss in an induction motor without causing the simultaneous existence of a copper loss in the exciting winding, friction and windage losses, and other types of core loss, so that great care must be exercised in considering what losses are actually measured, in any method of core loss determination used experimentally, if the results are to be of value. Before a method of testing is adopted, therefore, it is desirable to make a careful study of the manner in which the power represented by the losses is actually delivered from the electric circuit to the point of its ultimate consumption. The knowledge given by such a study is also indispensable in considering the results of tests.

On account of the importance of this subject the next several paragraphs will be devoted to its consideration.

The electric circuit of the stator and the shaft of the rotor are the only two sources of external power supply or consumption in the case of the normal induction motor. If a motor with an unwound rotor is considered it is evident that the only losses occurring in the rotor are iron losses and that all such losses must be supplied either by an external driving torque applied to the shaft or by a magnetic torque exerted at the air gap due to a current in the stator circuits. With steady running, the algebraic sum of the torques acting on the rotor is zero. Therefore, with friction and windage torque either known or constant, measurement of the external torque applied to the shaft will determine the air gap torque, which is due to the rotor iron losses. On this account it is relatively easy to determine experimentally the rotor iron losses independently of the existence of other losses. This facility of separate measurement, together with the fact that the theories of the rotor and stator iron losses are exactly similar, led to the decision to concentrate the experimental part of the research on the measurement of the rotor iron losses. Even after the air gap torque is known, however, it is not clear how the rotor iron loss is determined, so that a careful analysis of the relationships between speed and torque is necessary.

A rotating field produced by a smooth-core induction machine is equivalent to a revolving field magnet. As a result of hysteresis and eddy currents in the rotor (the rotor current may be considered as an eddy current), a displacement is produced between the stator m. m. f. and the flux, which displacement causes a torque proportional to the sine of the angle of advance. This torque opposes the relative motion of flux and rotor and hence tends to accelerate the latter when below synchronous speed and retard it when above. At exact synchronism there are no eddy currents in the rotor and the air gap torque is entirely due to hysteresis. This hysteresis is analogous to friction in that it produces only so much torque as may be necessary to prevent relative motion of flux and iron, subject to the limitation that it can not exceed a certain limiting value. Accordingly this torque may be either positive, negative, or zero and the rotor flux may either lag, lead, or be in exact phase with the revolving field magnet according to the amount of torque supplied from other sources.

The torque exerted upon the rotor takes from the electrical system power represented by $T_c\, \omega_s$ (where ω_s = synchronous ang. velocity and T_c = total torque due to the rotor losses). In overcoming friction, etc., this torque does mechanical work = $T_c\, \omega$ (where ω = angular velocity of rotor). Hence the power dissipated in the rotor is $T_c\,(\omega_s - \omega)$. Expressing this as an equation:

$$\underbrace{T_c\, \omega_s}_{\text{Power taken from stator and transmitted across air gap.}} = \underbrace{T_c\, \omega}_{\text{Mechanical work}} + \underbrace{T_c\,(\omega_s - \omega)}_{\text{Total loss in rotor}} \quad (\mathbf{28})$$

This equation adequately represents the distribution of the power consumed in the case of a smooth-core rotor revolving in a sinusoidal field, but in this case only. If harmonics exist in the field form which have different synchronous speeds from the fundamental, a similar equation to the above will hold true for each harmonic separately and the complete distribution of power will be represented by the sum of all the separate equations. In the calculation of losses, all harmonics having different frequencies in the rotor may as a first approximation, be treated independently since they can have no interactions except those due to temperature and saturation effects. In general, the rotor speed

2. A. E. Kennelly and P. L. Alger, Proc. A. I. E. E., Vol. XXXVI, Dec. 1917, p. 1113-1131.

ω, will be above the synchronous speed, ω_s, of some harmonics, and below that of others. Hence in some cases, $\omega_s - \omega$ and also T_c will be positive, and in other cases they will be negative or zero. Therefore the method of supply of the power is determined by the signs of the terms of this equation. There are three cases:

I. If $T_c\, \omega_s$ and $\omega\, T_c$ are both positive, all power is supplied by the stator electric circuit. $(0 < \omega < \omega_s)$

II. If $T_c\, \omega_s$ is positive and $\omega\, T_c$ is negative, power is supplied both electrically and mechanically.

$$(\omega < 0,\ \omega_s > 0)$$

III. If $T_c\, \omega_s$ and $\omega\, T_c$ are both negative, all the power is supplied mechanically, as by a driving motor.

$$(\omega > \omega_s)$$

Since the total air gap torque is the algebraic sum of the torques produced by all the harmonics, while the core loss is the sum of the products of the individual harmonic torques by their respective values of slip, $(\omega_s - \omega)$, it is necessary to analyze the observed torque into its components before the core loss can be obtained. It is thus seen that unless a sinusoidal field is used, important errors may result from the hasty conclusion that the total rotor core loss is measured by the product of the observed air gap torque, T_c, and the fundamental slip speed, $\omega_s - \omega$.

To make this more clear, consider the case of a revolving field containing a seventh harmonic revolving in the same direction as the fundamental but having a synchronous speed 1/7 as large, or $\omega_{s7} = 1/7\ \omega_{s1}$. Such a harmonic exists in the field produced by the usual three-phase winding. Then the observed air gap torque is:

$$\Sigma\, T_c = T_{c1} + T_{c7}$$

and the total rotor loss is:

$$\Sigma\, T_c\,(\omega_s - \omega) = T_{c1}\,(\omega_{s1} - \omega) + T_{c7}\left(\frac{\omega_{s1}}{7} - \omega\right),$$

quite different from:

$$(T_{c1} + T_{c7})\,(\omega_{s1} - \omega),$$

which is *apparently* equal to the total rotor loss. The latter expression is less than the former by an amount $6/7\ \omega_{s1}\, T_{c7}$ which represents the difference between the power actually supplied by the electric circuit and that which would have been supplied if all the torque had been delivered at a speed ω_{s1}.

So far, there has been considered only the case of a smooth-core machine, or one in which the air gap permeance does not vary. If this permeance does vary, due to the presence of slots, a further complication enters the energy equations.

It is a general principle that whenever any cyclic variations in the permeance of a magnetic circuit are caused by the relative movement of parts of the circuit, all the losses caused by this variation are supplied by the mechanical agency causing the motion. In the case of an induction motor running alone, this mechanical agency is the torque produced by the rotor current and fundamental core loss.

The proof of this principle for the case of a direct-current electromagnet whose keeper is cyclically moved follows directly from the facts that all the losses due to the motion are manifested in the same way as the pulsating currents induced in the magnet winding, and that these currents draw no power from the supply circuit since the product of an alternating current and a constant voltage gives a net power equal to zero. The proof in the more general case of an alternating-current circuit follows by analogy to the direct-current case, or may readily be proved by an application of Kelvin's law[3] to the power equation of the circuit.

In general, there are teeth on both sides of the air gap, and so pulsation losses due to permeance variations occur in both stator and rotor. All the pulsation losses are supplied by a mechanical torque just as friction is supplied, so that in the case of a normal motor a rotor current must flow which is large enough to supply a torque that together with the fundamental core loss torque, will overcome both pulsation and friction losses, while in the case of a motor with unwound rotor the fundamental core loss torque plus the externally applied driving torque must be large enough to overcome both these losses.

Calling T_p the torque necessary to supply all the pulsation losses in both stator and rotor, and T the accelerating torque supplied by a driving motor, we obtain for the correct loss equation:—

$$\underbrace{\Sigma\, T_c \omega_s + T_\omega}_{\text{Power from stator + power from driving motor}} = \underbrace{T_{f+\omega}\,\omega}_{\text{Friction and windage loss}} + \underbrace{T_p\,\omega}_{\text{Total pulsation loss}} + \underbrace{\Sigma\, T_c\,(\omega_s - \omega)}_{\text{Rotor core losses proper}} \qquad (29)$$

$$\text{or}\quad \Sigma\, T_c + T = T_{f+\omega} + T_p \qquad (30)$$

If the excitation is removed and ω is preserved constant, the applied torque, T, will increase until it equals the friction and windage torque. Hence the increase in the driving torque as the stator excitation is thrown off is equal to

$$\Delta\, T = \Sigma\, T_c - T_p \qquad (31)$$

From this discussion we may conclude that if ΔT, the change in the torque applied to the shaft of an induction motor as the excitation is thrown on or off, the motor speed being preserved constant, is measured by some form of dynamometer, this change in torque is a measure of the rotor core loss, subject to the following restrictions:

(a) If both rotor and stator have smooth cores so that no permeance variations occur, and if the stator m. m. f. is sinusoidally distributed around the periphery at every instant, then the product of $\Delta\, T$ and the slip, $\omega_s - \omega$, in watts, is exactly equal to the total core and copper losses occurring in the rotor.

(b) If there are no permeance variations, but the stator m. m. f. contains space harmonics which re-

3. Karapetoff, "The Magnetic Circuit," page 253.

volve at different synchronous speeds from the fundamental, ΔT is the algebraic sum of the torques due to the several harmonics, to each of which relation (a) applies separately. Before the total rotor loss can be known, ΔT must be analyzed into its parts, as each harmonic has a different value of slip.

(c) If permeance variations exist as a result of the rotation, ΔT is equal to the difference between ΣT_c and T_p, where $T_p \omega$ in watts is equal to the total pulsation loss occurring in both rotor and stator and $\Sigma T_c (\omega_s - \omega)$ is the total remaining rotor loss. Hence here also ΔT must be analyzed into its elements before any of the losses can be determined.

It is on the basis of these principles that measurements of rotor core loss were made in this research. That is, the change in the driving torque, ΔT, due to the stator excitation, was measured directly with dynamometer. There is, however, another convenient method of measurement of the rotor core loss which was used as an independent check. This latter method consists in the comparison of the total input to the electric circuit of the stator when the motor is running light with the input with rotor stationary. It will hereafter be referred to as the electrical method in contradistinction to the dynamometer method previously discussed.

The general energy equation reduces to (**28**) when no harmonics and no permeance variations exist. In this equation, T_c, representing the torque due to the total rotor losses, may be divided into two components due, respectively, to the hysteresis and the eddy current losses:

$$T_c = T_h + T_e \tag{32}$$

T_h, the hysteresis torque, is proportional to the hysteresis loss *per cycle*, so that it is independent of the frequency. T_e, the eddy current torque, is proportional to frequency, except at such high frequencies that damping and leakage reactance effects become appreciable. The frequency in the rotor is proportional to $\omega_s - \omega$, so that (**32**) may be expressed as:

$$T_c = T_h + E\,(\omega_s - \omega) \tag{33}$$

Substituting (**33**) in (**28**) there is obtained:

$$\underbrace{T_c\,\omega_s}_{\text{Output of stator to rotor}} = \underbrace{T_c\,\omega}_{\text{Mechanical work}} + \underbrace{T_h\,(\omega_s - \omega)}_{\text{Hysteresis loss}} + \underbrace{E\,(\omega_s - \omega)^2}_{\text{Eddy current loss}} \tag{34}$$

Suppose that the stator is excited with sinusoidal alternating current, the unwound rotor is driven by an external torque, and the electrical input to the stator is measured with wattmeters. When the rotor speed is below synchronism, or $0 < \omega < \omega_s$, the power input to the stator is:

$$\begin{aligned} P_s &= \text{Stator losses} + (T_h + T_e)\,\omega_s \\ &= C_1 + E\,\omega_s\,(\omega_s - \omega) \end{aligned} \tag{35}$$

That is to say, the hysteresis torque and the stator losses remain constant as the speed increases while the eddy current torque decreases linearly to zero as synchronism is approached.

At synchronism, the eddy current torque is zero, and the hysteresis torque may be either positive, negative or zero, just as the force of friction may have any value between limits before relative motion commences. Above synchronism, or when $\omega > \omega_s$, both T_h and T_e are negative, and the power input to the stator is:

$$\begin{aligned} P_s &= \text{Stator Losses} - (T_h + T_e)\,\omega_s \\ &= (C_1 - 2\,T_h\,\omega_s) - E\,\omega_s\,(\omega - \omega_s) \end{aligned} \tag{36}$$

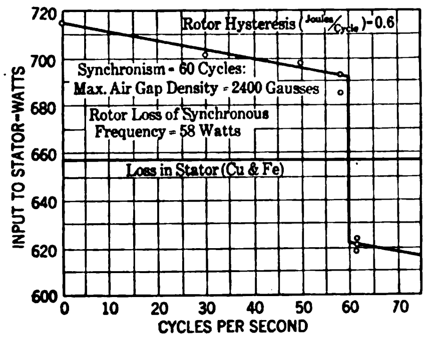


Fig. 4—Input to Stator With Rotor Rotating at Different Speeds

It follows from (**35**) and (**36**) that the difference between the stator electrical input at a speed just below synchronism and that at a speed just above synchronism is equal to $2\,T_h\,\omega_s$, or twice the hysteresis loss occurring in the rotor at line frequency. It also follows that the difference between the electrical inputs at zero speed and at a speed just below synchronism is equal to $E\,\omega_s^2$, or the total eddy loss in the rotor at line frequency.

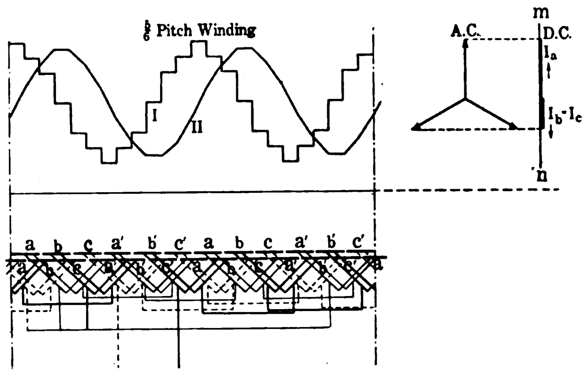


Fig. 5—Winding or Belt Diagram—5/6 Pitch
I. Current Distribution.
II. M. M. F Distribution.

The determination of the rotor losses by this process constitutes the electrical method of test. An experimental curve of stator input against rotor speed is shown in Fig. 4.

Experimental Work

In the preceding pages there have been described in turn the general object of the investigation, the theory of the first element of core loss to be investigated, and the theory of the testing methods employed. It remains to describe the experimental work performed.

A set of several interchangeable rotors and stators of 7-in. gap diameter with different numbers of teeth and different windings was collected for this research. The experiments to be described, which had as their object the determination of the losses due to the fundamental flux in a smooth-core rotor, were carried out with a smooth-core, Gramme ring-wound, three-phase two-pole stator and a smooth rotor without winding. The design data on this motor were as follows:

DESIGN DATA FOR SMOOTH-CORE SET.

Stator		Rotor	
Winding:	three-phase, two-pole ring-wound double-layer, 5/6-pitch.	Winding:	None
		No. of slots:	None
		Speed:	3600 Rev. per min.
Total conductors:	504, No. 20 B & S.	Peripheral Velocity:	110 ft. per sec.
No. of slots:	None	Gap Diameter:	6.81 in.
Frequency:	60 cycles.	Core length:	4.40 in.
Gap diameter:	7.00 in.	No. of 0.014-in. laminations:	212
Core length:	4.38 in.	No. of 0.034-in. "	7
		Material:	Best silicon steel laminations and brass spider.

Driving Motor: one-h. p., 115-volt d-c., rated 1800 rev. per min.
Magneto for speed measurements: Ball bearing type giving 10 volts at 1000 rev. per min.
Alternator for Power supply: three-phase, 15-kv-a. 20-70- cycle especially designed to give a pure sine wave e. m. f.

It was desired to produce in this rotor a perfectly sinusoidal flux distribution and to measure the resulting losses at various frequencies and flux densities. The sinusoidal character of the field was ensured by using as a source of power an alternator which had an e. m. f. containing no harmonics greater than 1 per cent of the fundamental and by disposing the stator winding in such a way as to secure a sinusoidal space distribution of m. m. f. Actually it was calculated that the 5/6-pitch ring winding used produced fifth and seventh space harmonics of m. m. f. of magnitude respectively 1.0 and 0.5 per cent of the fundamental. These figures are negligibly small, so that it is considered that the wave form of the flux actually produced in the air gap was satisfactorily near a sine wave. This belief was confirmed by oscillographic measurements of the flux with an exploring coil on the rotor.

Extra losses in the rotor were guarded against by the use of seven-mil paper insulation between laminations, and the provision of a brass spider. Extra losses in the stator were of no importance, since only the rotor core loss was measured. The very long air gap required by the use of a ring-wound stator made extra losses due to possible eccentricity of the rotor negligible. Care was taken to place the rotor centrally in the stator.

The test machines having been provided, it only remained to develop a suitable apparatus for the measurement of the losses. Four methods of core loss measurement were tried. The first method was to drive the rotor by a small direct-connected d-c. motor and to obtain the losses as the motor input less its output. This was unsatisfactory on account of the magnitude and variability of the losses in the d-c. motor. The second method was to measure the driving torque of the d-c. motor by means of a torsion spring dynamometer. This was very unsatisfactory on account of lack of sensitivity and the occurrence of severe vibrations at the high speeds used. The third, and most successful, method was to measure the core loss torque directly by means of a Webb floating dynamometer. The fourth method was the electrical

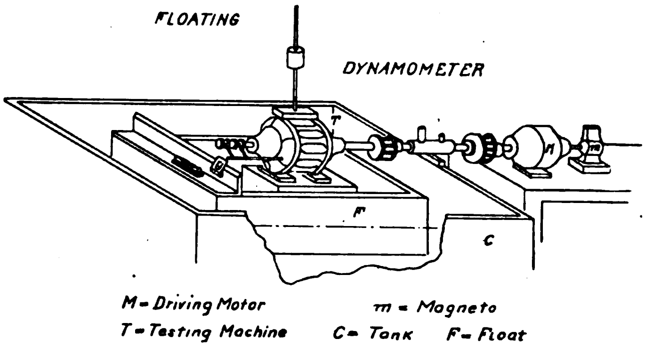
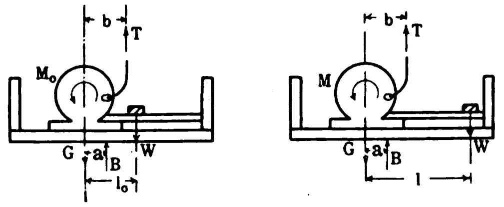


Fig. 6

method, previously described. Another method that could have been used, and which Bragstad[4] has used successfully for a like purpose, is that of determining the retardation of the rotor as it slows down when the driving torque is removed.

Since the total losses in this rotor varied between 5 and 100 watts under the conditions of test, their determination involved the measurement of a torque of the order of magnitude of 10^6 dyne ⊥ cm. (0.074 lb. ⊥ ft.). To obtain an accuracy of 5 per cent it is necessary to be able to detect readily a change in torque of about



Without Load With Magnetic Load

Fig. 7

50,000 dyne ⊥ cm., which means that a dynamometer of unusual sensitivity was required. The Webb floating dynamometer has the advantages of great sensitiveness, and of giving a null reading at the start. On account of the novelty and usefulness of this dynamometer, its construction and operation will be described in some detail.

This dynamometer consists essentially of a tank of water in which floats a substantial wooden box supporting the experimental motor. The motor is connected by means of a flexible coupling to the driving motor, which is placed on a stand external to the tank. The float is provided with movable weights, scales and levels enabling it to be adjusted to an exactly level

4. *Elektrotechnishe Zeitchrift*, Nov. 1908, p. 1074.

condition. A perspective view of the apparatus is presented in Fig. 6.

To operate the dynamometer, the driving motor is set in operation and brought up to speed, sufficient time is allowed to elapse for bearing friction and other changing conditions to become constant, and the float is carefully leveled. Any change in the torque transmitted by the driving shaft causes the float to tilt in a plane at right angles to the shaft, and the amount of this change in torque is readily measured by the couple represented by the shift in the weights necessary to restore the float to an even keel. Consequently by throwing the stator excitation on and off and successively relevelling the float, the core loss torque may be measured. Referring to Fig. 7, we have, with excitation off:

$$M_0 + B_a + T\,b - W\,l_0 = 0,$$

and with excitation on:

$$M + B\,a + T\,b - W\,l = 0,$$

whence

$$M - M_0 = W\,(l - l_0).$$

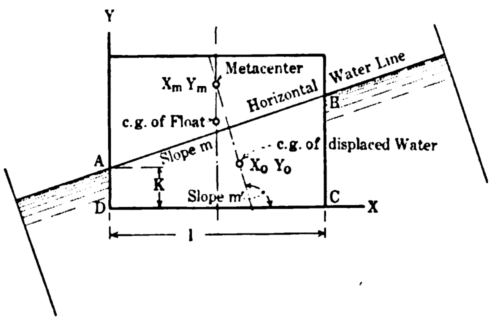


FIG. 8—LOCATION OF METACENTER

Or, the core loss torque is equal to the product of the balancing weight by the change in its lever arm.

The sensitivity of this dynamometer, or the angular tip per unit torque applied, is readily adjusted to any desired value by means of a weight sliding on a vertical pole in the center of the float. Raising this weight raises the center of gravity of the entire float, making it more top heavy, and consequently increases the sensitivity, while lowering the weight has an opposite effect. The measure of the sensitivity is the distance of the center of gravity of the float below the metacenter. The metacenter is the point of intersection of a vertical through the center of gravity of the displaced water with that principal axis of inertia of the float which is vertical at equilibrium. Fig. 8 presents this statement diagrammatically. If the center of gravity is above, at, or below the metacenter, the float will be in unstable, neutral, or stable equilibrium.

An evident objection to making the float very sensitive is the increased time required in coming to rest after a disturbance. The time of one oscillation of the float is approximately proportional to $\dfrac{1}{\sqrt{h}}$ where h is the height of the metacenter above the center of gravity. To secure satisfactory rapidity of operation coupled with high sensitivity the oscillations must be damped by hand. In practise the least change in torque it was found feasible to detect readily was about 40,000 dyne $\perp$ cm. (0.003 lb. $\perp$ ft.) or 1.5 watts at 3600 rev. per min.

Several experimental difficulties were encountered in operating of the dynamometer. In the first place, the end play of the motor shaft in its bearings caused the rotor to shift to and fro during a reading, thus varying the friction and causing errors in the measured torque. The magnetic pull of the field has a tendency to make the rotor position with field on different from that with field off, thus introducing a consistent error. Since the expense of providing ball bearings was prohibitive, this difficulty was met by mooring the float in position in the tank with horizontal elastic bands, which were stretched taut enough to hold the rotor in its position of magnetic equilibrium when the field was off. By reason of their being in a horizontal plane, the forces exerted by these cords did not affect the balance of the float, though they did have a tendency to damp out oscillation.

In the second place, the occurrence of large oscillations when the field was put on and off caused the sides of the float to get wet over an inch or more of free surface, and it was actually found that the inequality in the weight of water adhering to the wetted areas on the two sides of the float (equivalent to a film about 0.02 cm. deep) was sufficient to disturb the balance materially. This difficulty was surmounted by placing buffers to limit the oscillations of the float to a small arc.

A third difficulty lay in the vibrations produced by lack of balance in the rotating parts, which caused the float to execute forced oscillations. To overcome this difficulty it was necessary to carefully balance dynamically all revolving parts, and in fact a very considerable part of the total time spent on this research was devoted to study and experimental work in connection with this question of balance. The problem of balance was as difficult at speeds below 400 rev. per min. as at high speeds on account of the low natural frequency of oscillation of the dynamometer float.

The following data will convey a clear idea of the design of the dynamometer:

DESIGN OF FLOATING DYNAMOMETER.

	Tank	Float
Material	1 3/4-in. pine	1 3/8-in. pine
Construction		Box lined with tin.
Axial length, outside	52 in.	42 in.
Width "	48 in.	36 in.
Depth "	20 3/4 in.	18 in.
Immersed depth		8 in.
Weight of float proper		135 lb.
" " test machine, leads, and weights		320 lb.

In core loss measurement, the accurate determination of the rotor speed is of course an important factor

in the final precision attained. Throughout the experiments the speed was measured by a small magneto and voltmeter which were carefully calibrated at frequent intervals. The importance of knowing the speed accurately lay chiefly in the necessity for preserving precisely the same speed during torque measurments with the stator field on and with it off, in order to prevent the inclusion in the measurements of variations in the frictional torque. The

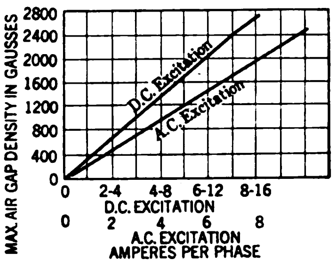


Fig. 9—Saturation Curve—Smooth-Core set

core loss torque itself does not vary rapidly with changes in speed. To secure this desirable constancy of speed, it was found expedient to use a storage battery as the source of power for the driving motor.

To furnish a basis for the calculation of the core loss, it was necessary to determine the gap density corresponding to any value of the stator current. A calibration curve giving the crest value of the sinusoidal flux wave in the air gap as a function of the phase current was obtained by means of an exploring coil of very fine wire encircling the rotor core. The ends of this coil were brought out to slip rings and the voltages induced in it at various speeds and excitations were measured with an electrostatic voltmeter.

By tests, the air gap flux was the same with three-phase alternating current as with an equivalent d-c. excitation of the stator. The final calibration curve is shown in Fig. 9. To secure a sinusoidal flux distribution with d-c. excitation, the current in one phase was adjusted to twice that in the other two, thus simulating the current values at the instant of a three-phase excitation at which the current in one phase is a maximum. The effective a-c. current per phase corresponding to this d-c. excitation is then $\frac{1}{\sqrt{2}}$ times the direct current in the over-excited phase.

Three sets of tests were made on the smooth-core rotor revolving in the smooth-core stator, as previously described, using the floating dynamometer to measure the torque due to the total core loss in the rotor. The first tests were made in the fall of 1915, and the others in the spring of 1916 after the dynamometer had been renovated in consequence of defects in its construction. In the first two tests the rotor was subject to vibration due to unbalance, in the last test it was perfectly balanced. All these tests were in the nature of trials in which the various experimental difficulties were successively encountered and overcome, so that their accuracy is not ideal.

The core loss torque was measured with five different excitations of the stator, using direct current. For each excitation, the torque was measured at several different rotor speeds, so that a chart showing the core loss as a function of speed and flux density was established.

The results obtained by the dynamometer method were calculated as follows:

The weight of the slider used to balance the float was 58.63 grams. Calling L (cm.) the displacement of the slider necessary to rebalance the float when the field was thrown on or off, the core loss torque, T, is:

$$T = 58.63\, L \times 981 = 5.75\, L \times 10^4 \text{ dyne} \perp \text{cm.}$$

and, calling the rotor speed in revolutions per minute N, the core loss is

$$W = \frac{2\,\pi\, N\, T}{60}\, 10^{-7} = 6.01\, L\, N \times 10^{-4} \text{ watts.}$$

The average core loss torque for each setting, in joules per cycle (watt seconds per cycle), is plotted against frequency in Fig. 10. The mean results of the first two sets of tests are indicated by small circles, the results of the third test by double circles. The first tests are believed to have given too high results because of changes in the rotor friction when the field was thrown on and off. The last set of tests is believed to be accurate as the rotor was perfectly balanced and the entire set operated very smoothly during the experiments.

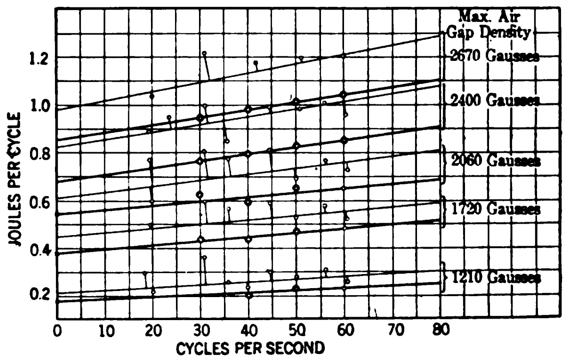


Fig. 10—Core Loss Torque vs. Speed for Smooth Rotor Obtained by Dynamometer.

In drawing the final representative lines on the chart, the earlier data were rejected, and only the final set of readings was taken into account, as shown by the heavy lines in Fig. 10. Further check tests which were planned, were prevented by the removal of the apparatus from Harvard to the new Technology buildings in the summer of 1916, and there has been no later opportunity to repeat them.

To check independently the dynamometer results, tests were also made by the electrical method previously described. The stator was excited with three-phase sinusoidal alternating current and the total

input was measured with wattmeters. The rotor was then driven up to synchronous speed by a driving motor, and the electrical input was measured, when the speed was just below and just above synchronism. In Fig. 4 there are illustrated the results of a test of this nature. The stator input falls linearly with increase in rotor speed until synchronous speed is reached, when it drops sharply, and then resumes its linear fall with further increase in rotor speed.

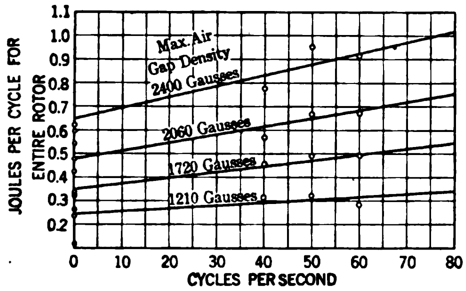


Fig. 11—Core Loss Torque vs. Speed for Smooth Rotor
Obtained by Electrical Method.

The chief objection to this method is that common to all difference methods. The rotor core loss is obtained as the difference of two relatively large quantities (about 10 times as large in this case), and hence can only be accurately determined by averaging a large number of tests. Since it takes an appreciable

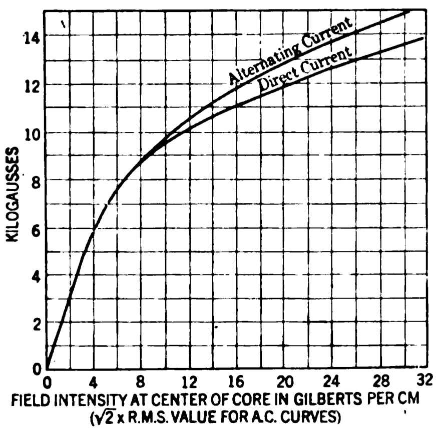


Fig. 12—Saturation Curve of Smooth-Core Rotor
Obtained by Transformer Method.

time for the rotor to come up to speed, changes in temperature of the stator during the interval between readings at zero and synchronous speeds may occur and cause changes in the stator losses, and hence important errors.

Fig. 11 shows the results of tests by this electrical method at four different excitations. The rotor core loss in watt seconds per cycle is plotted against the frequency in the rotor. The ordinates at zero speed were obtained by taking half the break in the stator watts input at synchronism and dividing it by the frequency. The experimental data are very inexact, and representative lines have been drawn without attempting to determine their most probable positions.

These lines agree roughly with the dynamometer results, the chief difference being that they indicate a larger percentage of eddy current loss.

Calculation of Losses

To furnish a basis for calculations of the core loss by the formulas derived in the earlier portions of this paper, the hysteresis and eddy current constants of the rotor core were determined by stationary tests, after the completion of the tests just described. The rotor shaft was removed from the spider and a ring winding

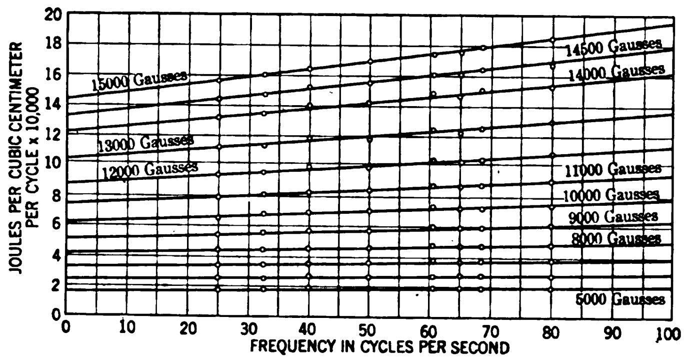


Fig. 13—Core Loss per Cycle vs. Frequency for Complete Smooth-Core Rotor
Determined by Transformer Tests under Sine Wave Voltage.

was placed around the rotor core, the wires passing through the openings between the spider arms. Exciting this winding from a sine wave source of voltage, the rotor core was magnetized with a tangentially directed alternating flux. Saturation curves for both a-c. and d-c. excitation are given in Fig. 12. The iron losses were measured by the wattmeter method with all the usual precautions against error.

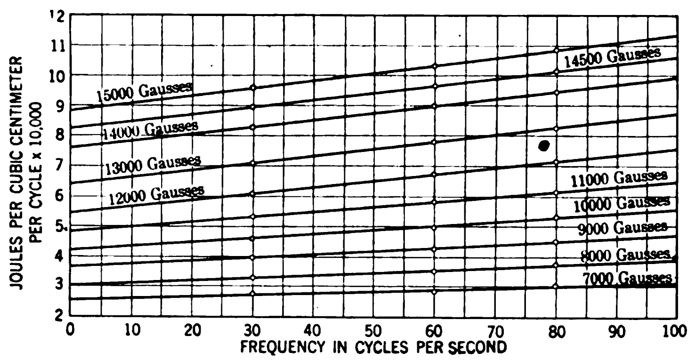


Fig. 14—Core Loss per Cycle vs. Frequency for Smooth-Core Rotor (Spider and End Plates Removed)
Determined by Transformer Tests.

The results of these tests are presented in Fig. 13. The core loss per cycle for constant density was found to be a linear function of the frequency, as expected. The losses thus found however, are considerably larger than (about thrice) the expected losses for this type of steel. To investigate this unexpectedly large loss, the rotor was taken down, the spider and thick end plates removed, and the 14-mil laminations were reassembled separately. Similar core loss measurements on the new core gave losses only about two-thirds as large as before. These results are shown in Fig. 14.

These excessive losses are attributed to the presence of three assembly notches on the inner periphery of the stampings and an extra notch in the outer periphery, all of which caused constrictions in the flux path and consequently increased losses. When the experiments were begun, the presence of the inner notches was not thought of, and the notch in the outer periphery was not considered a source of important extra loss. A scale drawing of one stamping is shown in Fig. 15.

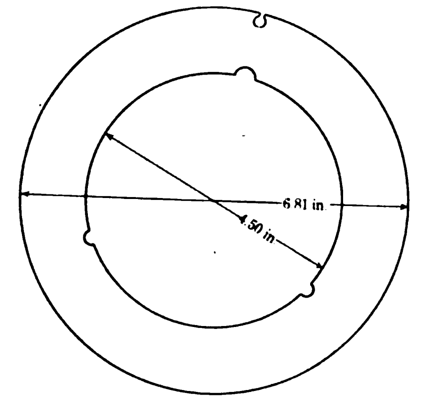


FIG. 15—SAMPLE LAMINATION OF SMOOTH-CORE ROTOR

Evidently the experiments just described uncovered a new source of disagreement between the measured core losses and the calculated ones.

The complete rotor core consisted of 210 fourteen-mil and 7 thirty-three-mil (end) laminations. The inner and outer radii were 5.72 and 8.65 cm. respectively. The over-all core length was 11.20 cm. of which 72 per cent was net iron length. The total volume of the core was 1065 cu. cm.

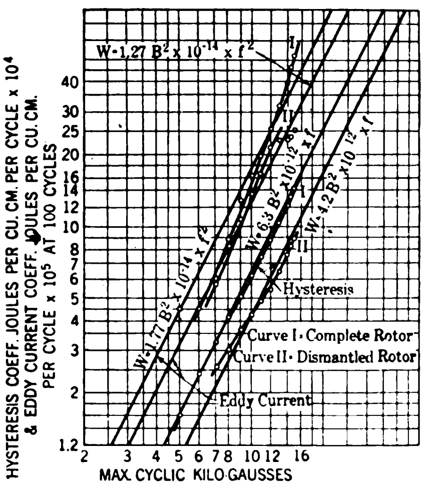


FIG. 16

By plotting data from Figs. 13 and 14 on logarithmic paper, representative equations for the core losses under alternating excitation were found to be, for the complete rotor:

Hysteresis loss
$= 5.3\ B^2 \times 10^{-12}$ joules per cu. cm. per cycle

Eddy loss
$= 1.77\ B^2 f \times 10^{-14}$ joules per cu. cm. per cycle

For the modified rotor:

Hysteresis loss
$= 4.2\ B^2 \times 10^{-12}$ joules per cu. cm. per cycle

Eddy loss
$= 1.27\ B^2 f \times 10^{-14}$ joules per cu. cm. per cycle

(B = max. flux density in gausses, f = frequency)

As Fig. 16 shows, the exponents of the density used in these formulas are not exact, but average values. The tests indicated a value of the eddy current exponent in excess of 2 and of the hysteresis exponent only a little less than 2. The reasons for the variable character of these exponents and the disagreement between observations by different investigators are probably to be found in the effect of the form of the magnetic path upon the wave form of flux variation. Although the total flux through the core undergoes a sinusoidal variation, the flux in each particular part of the core section undergoes its own form of non-sinusoidal variation which is determined by the variations in reluctance of the different sections during one cycle.[5]

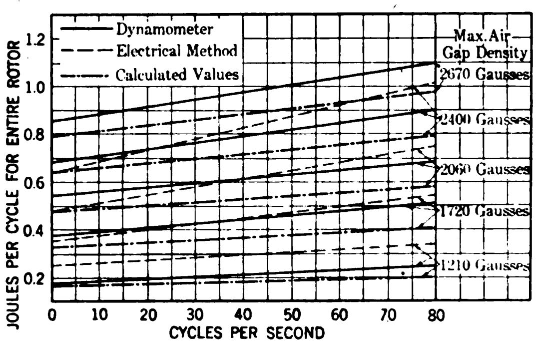


FIG. 17—CORE LOSS TORQUE VS. SPEED

Using the constants for the complete rotor thus determined, in connection with (**17**) and (**21**), the usual formulas for core loss, modified by multipliers K_1 and K_2 obtained from Figs. 2 and 3, the total hysteresis and eddy current losses were computed, added, and plotted on Fig. 17.

In these calculations the following constants were used:

$E = 4.42 \times 10^{-3}$ watts per cu. cm. at 50 cycles, 10,000 gausses.

$H = 3.15 \times 10^{-2}$ watts per cu. cm. at 50 cycles 10,000 gausses.

$a = Ra \div Ri = 1.51$

$L = 8.06$ cm.

$\phi = 47.0\ B_{max.}$ maxwells.

$B_{max.} = 4.11\ B_g$ maxwells.

B_g is the max. apparent gap density given in Figs. 9–11 inc.

$K_1 = 1.04$ (From Fig. 2. corresponding to $a = 1.51$, $P = 1$)

5. "Magnetic Flux Distribution in Annular Steel Laminae" by A. E. Kennelly and P. L. Alger, PROC. A. I. E. E. Dec. 1917, p. 1113.

$K_2 = 0.98$ (From Fig. 3. corresponding to $a = 1.51$, $P = 1$)

Inserting these constants in (**17**) and (**21**) there are obtained:

Eddy Loss

$= 1.95\, B_{max.}^2 f^2\, 10^{-11}$ watts for entire core.

Hysteresis Loss

$= 6.55\, B_{max.}^2 f\, 10^{-9}$ watts for entire core.

For the five excitations used in tests, the losses were calculated to be as follows:

D-c. Exc. amps.	3-1/2-7	5-10	6-12	7-14	8-16
F_g	1210	1720	2060	2400	2670
B max W 4.11 P_g	4970	7070	8470	9870	10990
Hyst. Watts/cycle/sec..	0.162	0.327	0.470	0.638	0.790
Eddy Watts/cycle/sec..	0.029	0.059	0.064	0.114	0.141
Total watts/cycle/sec. at 60 cyc............	0.191	0.386	0.554	0.752	0.931

A comparison of these calculated values with the test values, which are also shown in Fig. 17, brings out the fact that the former are uniformly too low. This is especially true in regard to the eddy current loss.

The real object of the investigation was to determine values of K_1 and K_2 by which the results given by the usual formulas should be multiplied to obtain correct results. Theoretical values of K_1 and K_2 based on the assumption of constant permeability were obtained and plotted in Figs. 2 and 3. These values give, at all points within the usual range of values of a and P in induction motor design practise, core losses not more than 10 per cent lower or 30 per cent higher than those given by the usual formulas. The test results are not accurate enough to obtain reliable values of K_1 and K_2 from, but they do show that the usual (as well as the new) formulas give a total core loss correct within 50 per cent.

The net result of the investigation is to establish a strong presumption that the cores back of the teeth are not the seat of any important extra losses and that the usual formulas (**17**) and (**21**) are sufficiently accurate for practical purposes, provided the correct iron loss coefficients, E and H are used in them. Due to the varying permeability, the true value of E is always larger than the apparent value derived from Epstein tests on straight samples or from the resistivity. But H is the more important of the two coefficients, and this is not much in error when obtained in the usual way.

As a general rule, the total core loss in an induction motor is from two to three times the calculated fundamental frequency losses in the core and teeth. Since it has been shown that probably no important part of these extra losses occur at fundamental frequency in the cores, and it seems evident that they can not be in any measure due to fundamental frequency flux inthe teeth, it appears that they are due to the tooth frequency pulsations. The probability, thus established, that the tooth frequency losses constitute from one-half to two-thirds of the total core loss in the average motor is of great importance. This shows at once the futility of calculating core losses without allowing for tooth frequency effects and also it shows the great possibilities that exist for the reduction of the core losses now tolerated. Slight changes in the numbers and shape of the teeth make large changes in the tooth frequency losses.

As a matter of fact, the total observed core losses can reasonably be accounted for by calculating the eddy and unsymmetrical hysteresis losses due to the tooth pulsations, and the pole face losses in the tips of the teeth due to the variation of gap density from tooth to slot, and adding these losses to the usually calculated fundamental frequency losses. In calculating the pulsation losses the copper losses and the damping effects of tooth frequency circulating currents in the rotor winding must be taken into account. The magnitudes of the undamped tooth pulsations may be quite accurately computed with the aid of Carter's formulas for fringing.

Review

To epitomize the work on the losses in a smooth annular core, it may be said that it was projected to determine a rational formula for these losses by the comparison of accurate experiments under controlled conditions with theoretical formulas, and that every step necessary to carry out that project was completed. At each step new sources of error were uncovered whose cumulative effect made it impossible to draw as detailed conclusions as had been planned. In short the work so far accomplished has provided only a part of the results aimed at.

To calculate the core loss theoretical formulas and empirical constants must be obtained. In developing a theoretical formula the errors of the usual formula (neglect of losses due to radial components of flux and assumption of uniform flux distribution) were avoided, but a new error (assumption of uniform permeability) was introduced by the lack of an adequate mathematical method of treatment. In determining the empirical constants the errors inherent in the usual method (attributing the properties of a sample of a different shape and possibly different lot of iron to the iron under test) were avoided by determining the constants for the test core directly. But the errors consequent upon the test core not being of the perfect annular shape ascribed to it were not avoided.

To measure the losses experimentally requires the development of an accurate method of measurement and of means of producing exactly the desired conditions of flux distribution. Two methods of measurement were developed and so far perfected as to give fair uniformity and agreement, though certain sources of error were not eliminated. The desired conditions of flux distribution were produced quite nearly by use of a carefully distributed 5/6-pitch

stator winding and a long air gap. The errors here, due to saturation and harmonics in the m. m. f., were satisfactorily small.

The only previously published paper that deals particularly with the fundamental frequency losses in a smooth-core rotor is, so far as known to the authors, that by R. Czepek in the *Elektrotechnik und Maschinenbau* for 1910, p. 325. In that article, Czepek described experiments on the losses in a smooth core produced by an alternating and by a revolving field. Comparing the results of his tests, Czepek concluded that the losses produced by a revolving field were considerably larger than those computed from constants derived from alternating magnetization tests; a conclusion distinctly opposed to that drawn from the results of the present paper. The reason for the disagreement in the conclusions probably lies in the fact that Czepek used a salient pole machine for his tests and that, consequently, the revolving field he used was quite far from sinusoidal. An oscillogram of the field wave form given in the article shows this distinctly.

In carrying out further work on core losses it will be very desirable to make use of larger machines, since the ratio of the friction and copper losses to the core loss, and hence also the errors in the separate measurement of core loss, are inherently greater the smaller the machine is. It will also be very desirable to develop an adequate mathematical treatment of the losses under variable permeability.

The element of the core loss that appears of greatest importance for future investigation is that due to pulsations in the teeth. The investigation of this loss should include first an investigation of the magnitudes and damping effects of circulating currents in the secondary, and second an extended investigation of unsymmetrical hysteresis. The subject of circulating currents due to tooth pulsations seems never to have been treated. That of unsymmetrical hysteresis is still open to discussion, since published researches have so far dealt only with the loss due to the addition of a small displaced hysteresis loop to the unchanged fundamental loop; while it is probable that the area of the latter loop is markedly changed by the presence of the former.

The principal definite results of the work on this research are:

(a) New formulas for the losses in the core back of the teeth have been developed, and multipliers for the usual formulas derived therefrom have been made available for convenient use by charting in Figs. 2 and 3. These charts indicate that the errors of the usual formulas due to neglect of the losses produced by the radial component of the core flux are not large except when excessively deep cores are used.

(b) Complete tests and calculations have been carried out on a smooth-core rotor revolving in a smooth stator and the observed losses compared with the expected losses, with the result of confirming the theoretical expectation that the errors of the usual formulas (**17**) and (**21**) are not serious in ordinary practise.

(c) As a result of (a) and (b) and the known fact that the total core losses in usual induction motors are from two to three times the fundamental frequency losses as calculated by the usual formulas, a strong presumption has been established that the tooth frequency core losses constitute from one-half to two-thirds of the total in ordinary induction motors.

(d) It has been experimentally demonstrated that the hysteresis torque due to a revolving field breaks abruptly through zero at synchronous speed. (Fig. 4.)

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NATIONAL ELECTRICAL SAFETY CODE

The new edition of the National Electrical Safety Code is being printed by the Bureau of Standards. This code has been in the course of development for seven years. Preliminary drafts were circulated and criticized and the complete edition of the code was published in 1916 for trial use and constructive criticism. The new edition is expected to be made mandatory by state and city officials having appropriate jurisdiction. The rules of this code deal with the construction, installation and operation of electrical machinery and devices. They apply to practise in generating stations, to outdoor lines used in transmission and distribution, and to the installations of equipment found in factories, offices, theatres and other places where electrical energy may be applied.

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MEETING AT PHILADELPHIA

FRIDAY, OCTOBER 8

The first Fall meeting of the American Institute of Electrical Engineers will be held in Philadelphia, Friday, October 8th.

The headquarters of the Institute during the meeting will be at the Bellevue-Stratford Hotel, Broad & Walnut Streets.

The afternoon session will begin at 2:30 p. m. in the Clover Room of the Bellevue-Stratford Hotel and two papers will be presented, as follows:

Economic Study of Secondary Distribution, by P. O. Reyneau and H. P. Seelye, both of the Detroit Edison Co.

Electrical Demand Measurements, by P. A. Borden, of the Ontario Power Commission.

At 6:30 p. m. an informal subscription dinner will be served to members and guests of the Institute in the Stratford Room of the Hotel.

The evening session will be devoted to the celebration of the 100th anniversary of the important early discoveries of Arago, Ampere, Davy and Oersted. The principal speakers at this session will be Dr. Elihu Thompson and Dr. M. I. Pupin.

Replicas of apparatus used by the pioneer discoverers in some of their experiments will be exhibited.

The Board of Directors of the Institute will hold its regular monthly meeting at 10:30 a. m. at the Bellevue-Stratford and a meeting of the Meetings and Papers Committee will be held at 9 a. m. Other committee meetings will be held in accordance to notices sent to committee members.

Program

FRIDAY, OCTOBER 8th

8:30 A. M.

Registration office opens.

9:00 A. M.

Meetings and Papers Committee.

10:30 P. M.

Meeting of Board of Directors.

2:30 P. M.

Technical Session

Economic Study of Secondary Distribution, by P. O. Reyneau and H. P. Seelye.

Electrical Demand Measurements, by P. A. Borden.

Discussion.

6:30 P. M.

Informal Subscription Dinner at Bellevue-Stratford. Price $3 per cover.

8:30 P. M.

Anniversary of Early Discoveries.

Address by Dr. Elihu Thomson.

The epoch making discoveries of the years 1819 *and* 1820 *with special reference to the work of Ampere, Arago, Davy and Oersted.*

Address, by Dr. M. I. Pupin.

The significance of the discoveries of Ampere, Arago, Davy and Oersted in the development of science in the past hundred years.

There will be exhibited replicas of apparatus used by the pioneer discoverers in some of their experiments which have been very kindly prepared for this occasion by Prof. Harold Pender.

NOVEMBER MEETING

The November meeting will be held in Chicago on November 12, 1920, and will be under the auspices of the Protective Devices Committee. The principal paper of the meeting will be by Mr. D. W. Roper, Chairman of the Committee, on the subject of Lightning Protection.

TELEPHONE STATISTICS SHOW BUSINESS DEVELOPMENT IN SOUTH AMERICA

Striking figures showing the development of South and Central American Republics are made public as a result of a survey by the American Telephone and Telegraph Company. These statistics, which were prepared with the cooperation of the various governments, cover the telephone and telegraph systems of all the countries south of the Rio Grande. Some of the conclusions reached from the survey are that in the Southern countries the telephone is far from being the universal means of communication that it is in this country and that the main development there is in the big cities, the other areas being very poorly served. The telephone network is about a hundred times as dense in this country, as a whole as it is there. In point of the number of telephones per hundred of population, the service here is over thirty times as good.

The total of 325,403 telephones in all the South and Central American countries including Cuba and Haiti, should be compared with the twelve million in the United States, which have about the same total population. Argentine leads with 105,205 telephones, or nearly a third of the total. The other countries having more than 10,000 telephones are: Brazil, 67,366; Mexico, 40,211; Cuba, 28,152; Chile, 23,670 and Uruguay, 19,486. Haiti with a total of 2,500,000 people, has 82 telephones.

Only one telephone for about every 300 population is found in the whole area, as compared with 11.39 for every hundred of population in the United States at the same date, or about 34 for every 300 population. Uruguay leads Latin-American countries in point of telephone density with 1.34 telephones per hundred people. The only other countries having as much as one telephone per hundred population are Argentine, Cuba and Panama. In the three countries having the highest telephone development, the systems are almost wholly under private ownership.

The extent to which the countries are served by their systems is indicated by the figures showing the telephone development in the largest city in each country. Havana, Cuba, is the most highly developed, with 5.5 telephones per hundred population. Taking in all of Cuba, however, there is only one telephone per hundred people. Mexico City has 3.9 per hundred—Mexico as a whole has only 0.25 telephones per hundred population. These figures show how in the Southern countries the bulk of the systems is in the large cities, while the other areas are hardly served at all. This condition is contrasted with that in the United States. At the same date New York City had 11.7 telephones per hundred people—the United States as a whole had nearly as many, 11.39. Here is adequate service for even the smallest farm communities.

The investment in telephone systems in all the Southern countries together is $64,422,000 compared with $1,600,000,000 in the United States. The per capita investment is 71 cents in South America compared with $15.09 here. The highest investment is in Cuba, $2.28 per capita. The investment per telephone is perhaps even more significant. In Latin-America there is invested $198 for every telephone in service—in the United States this is only $132. These figures reflect the higher technical progress and the more efficient mangement, as well as the greater density of development, in this country.

The gross earnings in 1918 of South American telephone systems were only eighteen cents per capita while in this country they were $3.99. The gross earnings per telephone were, however, $52.82 down there and only $34.98 here.

Of the total telephone and telegraph earnings in 1918 in the Latin countries, the telephones brought in only 43.5 per cent of the total and the telegraph 56.5 per cent. In the United States this situation is strikingly reversed—80.8 per cent from the telephones and 19.2 per cent from telegraphs. The total telegraph wire mileage is 433,938 down there and 1,900,000 here. The number of offices are 11,627 and 28,900 respectively. The number of messages sent in 1918 was 41,517,200 in the Southern countries as compared with 170,000,000 here.

The telegraph statistics therefore show a more favorable comparison with those of this country than do the telephone figures. The reason is that the telegraph is more used by a specialized class of the population mainly for business. The telephone has not in the Latin-American republics come anywhere near being the universal and democratic means of communication that it is in the United States.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

NATIONAL SERVICE DEPARTMENT OF ENGINEERING COUNCIL

When the Engineering Council announced that its National Service Department was prepared to assist engineers in obtaining such information as they wanted from the National Legislative and Executive Department. a great many engineers took advantage of this opportunity. Individual engineers as well as engineering organizations, will find the Washington office a useful medium, through which to keep in touch with National affairs and to bring their recommendations, their grievances or inquiries before government officers.

This is one of the important features that goes with membership in the A. I. E. E. and other societies which organized Engineering Council, and members should feel very free to call upon the Washington office whenever it can be of assistance. It is in charge of M. O. Leighton, National Service Representative of Engineering Council, 700 10th St. N. W., Washington, D. C.

TECHNICAL WORK AT THE BUREAU OF STANDARDS

Recent bulletins issued by the Bureau of Standards cover the progress of experimental work that has been started there. The titles of those that are of especial interest to engineers are itemized below: Permeability of Concrete.

Investigation of Combination of Aluminous and Siliceous Bond Clays Used in Making of Crucibles.

National Electrical Safety Code.

Method for the Accurate Measurement of the Interior Diameter of Ring Gages.

The Use of Etched Balls in the Brinell Test of Hardened Steels.

Properties of Boiler Plate at Elevated Temperatures.

Test of a Section of a Cast Iron Heating Boiler.

Because of the current nature of these investigations, the results are not generally printed, but complete data on all work to date is always obtainable through the National Service Department at the Washington office of Engineering Council, or from the Bureau direct.

ENGINEERING COUNCIL ADVISES THE FEDERAL POWER COMMISSION

At the invitation of O. C. Merrill, executive officer of the Federal Power Commission, the Water Conservation Committee of Engineering Council has submitted advice with respect to regulations covering certain important features of the administration of water powers, to be licensed under the Water Power Act. To Mr. Calvert Townley, Past-President of the American Institute of Electrical Engineers and also Chairman of the Water Conservation Committee of Engineering Council, Mr. Merrill submitted specific inquiries relating to rental charges for water power licenses, including charges covering cost of Federal administration, use of Government lands and property, tribal lands within Indian surveys and use of Government dams. Other inquiries were, the basis of exappropriation above a specific rate of return; readjustment of charges, benefits from headwater improvement, depreciation and amortization and finally allocation of earnings.

The Water Conservation Committee met at Washington on September 10th, spending the entire day in conference on the above named subject. The following day was spent in conference with the staff of the Federal Power Commission in discussing principles and points of view in preparation for the formal report of the Conservation Committee on the subjects.

The invitation given to Engineering Council to take up the above named matters in advisory capacity is but another of the instances which of late have become increasingly frequent, that the Government has recognized the value of organized engineering consideration in Government engineering matters.

FEDERATED AMERICAN ENGINEERING SOCIETIES

PROGRAM OF THE FIRST MEETING OF AMERICAN ENGINEERING COUNCIL

Washington, D. C., November 18-19, 1920

The headquarters of the meeting will be at the New Willard Hotel and all sessions will be held in the Small Ball Room.

Thursday, November 18, 1920

MORNING SESSION

8.30 A. M. Registration.

10.00 A. M. Opening Session of American Engineering Council

1. Call to order.
   Richard L. Humphrey, Chairman,
   Joint Conference Committee,
   Consulting Engineer,
   Philadelphia, Pa.
2. Election of Temporary Chairman.
3. Election of Temporary Secretary.
4. Appointment of Temporary Committees:
   (a) Program
   (b) Credentials
   (c) Constitution and By-Laws
   (d) Nominations
   (e) Plan and Scope
   (f) Budget
   (g) Resolutions.

AFTERNOON SESSION

2.00 P. M. Address, "Engineering Council," J. Parke Channing, Chairman, Consulting Engineer, New York, N. Y.

2.30 P. M. Discussion of the field of activity for The Federated American Engineering Societies.

Friday, November 19, 1920

MORNING SESSION

9.00 A. M.
1. Report of Committee on Nominations.
2. Election of Permanent Officers.
3. Report of Committee on Constitution and By-Laws.
4. Formal Ratification of Constitution and By-Laws.
5. Report of Committee on Plan and Scope.

AFTERNOON SESSION

2.00 P. M.
1. Report of Committee on Budget.
2. Report of Committee on Resolutions.

EVENING SESSION

8.30 P. M.
1. Introductory remarks by presiding officer, the President of American Engineering Council.
2. Address by Herbert C. Hoover, President, American Institute of Mining and Metallurgical Engineers, New York, N. Y.

9.30 P. M. Informal reception and smoker.

Saturday, November 20, 1920

9.00 A. M. Organization Meeting, Executive Board, American Engineering Council of The Federated American Engineering Societies.

ADDITIONAL SOCIETY ACTION

The Cleveland Engineering Society at its meeting on August 10 voted to become a Charter Member of The Federated American Engineering Societies.

EACH SOCIETY AUTONOMOUS

The manner of selecting representatives on the American Engineering Council has been criticized as being undemocratic and it is stated that,

The engineers of the United States today number at least 100,000—possibly 200,000. Within a decade or two it is not impossible that this may be increased to 500,000. Anything short of an effort to bring every one of these engineers individually into the fray by giving them a direct vote and otherwise, would be in the first place to go counter to every modern tendency in democratic theory, but of even greater immediate importance, it would deprive the new Federation of the most obvious means of educating and gradually enthusing the rank and file. This is just the kind of opportunity which was missed in the failure to provide that the members of the American Engineering Council should be elected by the votes of the members of the constituent organizations rather than by the boards of these organizations.

The Organizing Conference at Washington, by unanimous vote decided that the Federated American Engineering Societies

Should be an organization of Societies or affiliations and not of individuals.

The Constitution and By-Laws that it adopted provide that each organization shall be autonomous. In keeping with this principle of autonomy, it is the intent of the Constitution and By-laws that each representative on American Engineering Council shall be selected by the organization he represents in any manner it deems wise or expedient.

The Joint Conference Committee feels that the election of representatives by the direct votes of the members of each organization is desirable and should be supported in principle, but it is not a question that is vital at this time to the success of American Engineering Council.

If it were required that the representatives on American Engineering Council should be elected by the direct votes of the members of the constitutent organizations, many organizations would be obliged to delay becoming members for some time while changes were being effected in the Constitution and By-Laws of these organizations. As a matter of fact some of the organizations who have become members of The Federated American Engineering Societies will probably elect their representatives by the direct votes of the members of these organizations.

The Joint Conference Committee is confident that American Engineering Council, composed of representatives of national, local, state and regional organizations and affiliations from or representing all parts of the country, no matter in what manner they may be selected, will be truly a representative and democratic body free from the criticism that it does not properly and efficiently represent the engineering and allied technical professions.

FORM OF ORGANIZATION SATISFACTORY

In discussing the question of whether The Federated American Engineering Societies should be an organization of individuals or societies, a current bulletin of a local engineering society states,

We may infer * * * * * that the American Association of Engineers does not intend to enter the Federation and that we have here a distinct line of cleavage between a democratic and federalized organization. We are to choose which type of organization is to rule the destinies of the engineering profession. Our federal constitution provides for government of delegated powers composed of elected representatives, and we confess to a preference for that form of association of engineers modelled after that famous document which has been the model of the world for nearly a century and a half.

* * * * *

It would seem, therefore, that we have not yet brought about cooperation among engineers in its most effective form. Are we to be divided into two camps? It looks very much like it now.

As this statement is likely to be misleading, the Joint Conference Committee would point out that at the Organizing Conference in Washington, the delegates of the American Association of Engineers, which included its retiring and its incoming President, stated that,

We will cooperate on any basis you will permit us to cooperate upon. . . . We are here to support you, to give you all support, and insofar as we are able, our financial support in anything that will advance the welfare of the engineer.

The Joint Conference Committee does not feel that there is any danger of cleavage in the engineering profession, for the reason that one of the principles on which The Federated American Engineering Societies is founded is non-interference with the autonomy of each engineering and allied technical organization. The field of activity of this organization is that already undertaken by Engineering Council, which work will be extended and carried on in a more representative and comprehensive way. The Federated American Engineering Societies will not in any way be a competitor of existing organizations, and the Joint Conference Committee believe that its work will receive the hearty and effective cooperation of all engineering and allied technical organizations in this country. The most representative and important conference of engineers in the history of this country by unanimous vote decided on the present form of organization and it would seem logical, therefore, that the engineering and allied technical organizations should give it a trial and subsequently correct such defects as develop.

The Joint Conference Committee is confident that there are no defects in principle, but, as was pointed out at the Washington Organizing Conference details must obviously be subject to such changes as may, by experience, be found desirable.

The Joint Conference Committee appreciates that the conservative engineer wishes to weigh and consider, and be cautious about embarking on new enterprises. The Federated American Engineering Societies is not a new enterprise as has been repeatedly pointed out; the governing body of the organization, American Engineering Council, will succeed on or about January 1, 1921, Engineering Council which has as Member Societies the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Society for Testing Materials, and the American Railway Engineering Association. This organization, after three years of existence, is a proved success and has demonstrated the great need for a comprehensive body that will speak for the engineering and allied technical professions in matters of public welfare where engineering experience and technical training are involved, and in matters of common concern to these professions.

FINANCING THE FEDERATED AMERICAN ENGINEERING SOCIETIES

The Organizing Conference consisting of 140 delegates from 71 national, local, state and regional engineering and allied technical organizations and affiliations, representing an aggregate membership of over 110,000 or more than 80 per cent of that of all the organizations invited to participate, unanimously adopted the following resolutions, at Washington, June 3-4, 1920.

RESOLVED, that it is the sense of this Organizing Conference that an organization be created to further the public welfare wherever technical knowledge and engineering experience are involved and to consider and act upon matters of common concern to the engineering and allied technical professions.

RESOLVED, that it is the sense of this Conference that the proposed organization should be an organization of societies or affiliations and not of individuals.

The Joint Conference Committee in its report to its four constituent societies in September, 1919, unanimously recommended, the formation of a single comprehensive organization to secure united action of the engineering and allied technical professions in matters of common interest to them.

The Committee emphasized,—

that the plan can only be valuable and enduring as the motive dominating it is patriotic, broad-visioned and unselfish* * * *

The great object is to provide an effective body, widely and truly representative, modestly yet adequately financed, which will be neither autocratic nor aristocratic,* * * * * *.

The Committee pointed out the essential requirements of such an organization in the following recommendation:

Every new activity, to be effective, means work and needs money. A movement such as proposed, if undertaken without sufficient funds, would not only prove barren of results, but by failure would bring ridicule upon the profession. In advance of its organization no definite budget can be prepared. The revenues proposed are moderate, and are based on the experience of Engineering Council, which while called upon to occupy an ever-widening field, has been continually handicapped by limited resources.

As was pointed out previously, the annual income of Engineering Council never exceeded \$22,000. In considering the needs of the proposed organization, it was the unanimous opinion of the Joint Conference Committee and of the representatives of Engineering Council, that the minimum annual budget should be \$50,000. The reason for the larger budget for the proposed organization is that Engineering Council through the courtesy of the United Engineering Society, occupies quarters in the Engineering Societies Building free of charge and enjoys the services of a paid staff for which only a portion of their salaries are charged. When the American Engineering Council comes into existence, it must assume these expenses, which will be paid out of the contributions of its Member Societies. Another reason for the increase in this budget is that the Committee has been advised by the representatives of Engineering Council that its activities have been greatly curtailed because of the handicap of inadequate funds.

It was further deemed desirable, at least during the earlier years of the existence of the organization, that the representatives on the national council and the members of its Executive Board should be allowed mileage in order to insure a full attendance at meetings of these bodies; and allowance of \$25,000 was made for this purpose making a minimum annual budget of \$75,000.

The question then arose as to the best means of providing this income. It was agreed that the Member Societies of the organization should make contributions to cover the amount. The question naturally arose as to the basis for these contributions, since obviously a local society of 100 members could not reasonably be expected to make as large a contribution as a national society of several thousand members, nor could a national society of 300 or 400 members pay as large a contribution as one that had more than 10,000 members. The Committee took into further consideration, the ability of a local, state or regional organization or affiliation, to raise money as against that of a national society and it decided that the proportion paid by the former should be less than that paid by the national societies. In the final analysis the decision was reached that a proper basis of contribution would be the number of members in the organization, that is, an annual per capita basis, which was fixed for the national societies at \$1.50, and for the local, state and regional organizations and affiliations at two-thirds of this amount, or \$1.00 per member.

By reason of the fact that the individual member is the basis of assessment, some organizations make the mistake of assuming that there are individual dues in The Federated American Engineering Societies. Such is not the case. As above stated, each Member Society makes an annual contribution for the support of the work. This is determined on the pro rata basis per member indicated.

The basis of the contribution of a local, state or regional organization or affiliation member of The Federated American Engineering Societies, is the aggregate membership represented, with-

out regard to the fact that some of its members may be members of national organizations which are members of The Federated American Engineering Societies.

The basis of the contribution of a state organization to The Federated American Engineering Societies would be the aggregate membership in the state. If, however, one or more of the local organizations in the state already held membership in The Federated American Engineering Societies, then the basis of contribution of the state organization, would be the aggregate membership of the state, less the membership of the organizations which already held membership in The Federated American Engineering Societies.

The Committee has been frequently asked why the individual member should contribute more than once to the support of this organization. That is, if a member of a local organization holds membership in a national organization which is a member of The Federated American Engineering Societies, why should the local organization contribute again for him as a member of the local organization? The Joint Conference Committee considered the question of having the individual engineer and allied technologist interested in The Federated American Engineering Societies through the membership of the organization of which he was a member, and, whether it would be wise to make an individual assessment for dues of $5.00 per annum. If this plan of procedure had been followed the question that has just been discussed would not have arisen. On the other hand, the Committee felt it would work a hardship on some individuals, and, in its judgment when an engineer or allied technologist had advanced sufficiently in his profession to be able to join more than one society he would be in a position to pay a higher contribution per capita than the man who is a member of only one society. It, therefore, seemed logical, in lieu of a flat per capita assessment, to make the basis of a contribution of $1.50 in the case of a national organization and $1.00 in the case of a local, state or regional organization or affiliation. This undoubtedly means that the organizations of which the individual is a member must pay per capita contribution for him as above indicated; in the last analysis the per capita amount must be paid as many times as the individual is a member of organizations which hold membership in The Federated American Engineering Societies.

It is unreasonable that an engineer or allied technologist who has representation in The Federated American Engineering Societies through a national organization should expect also to have representation through a local or other organization that is a member of The Federated American Engineering Societies' without an additional payment for this representation. If he is a member of more than one organization that holds membership in The Federated American Engineering Societies, then he must pay for each representation.

Assuming an engineer is a member of six national and one local organization which have membership in The Federated American Engineering Societies he would contribute annually through his dues $10.00 to The Federated American Engineering Societies. The question that the individual engineer and allied technologist should ask himself is whether the advancement of the proper standing of his profession and the maintenance of a means whereby it is a factor in the affairs of the community, state, and nation, is worth an annual payment of this amount, even though he is a member of seven organizations which have membership in The Federated American Engineering Societies.

If the engineering and allied technical profession is to take its proper place in public affairs it must have some organization that will act as a medium for the expression of such service, and this organization must be financed. Each individual engineer or allied technologist should be willing to contribute at least $10.00 per annum for this cause, although, on the basis provided, the average per capita contribution will probably not exceed one-third of this amount.

SUMMARY OF INFORMATION

Who are and who should be interested. The Organizing Conference held in Washington, June 3-4, 1920 was attended by 140 delegates representing over 71 organizations, having an aggregate membership of over 110,000, or, over 80 per cent of the aggregate membership of all of the organizations that were invited. The questions have been asked:

"Who are these men?"
"Who were invited?"
"Who should be interested in this movement?"

The Federated American Engineering Societies is constituted of engineering and allied technical organizations, whose chief purpose is the advancement of the knowledge and practise of engineering and allied technical arts, which are not organized for commercial purposes. It includes the individual engineer and the allied technologist who is represented through the society or societies of which he is a member, which have membership in the organization. It includes civil, mining, metallurgical, mechanical, electrical, testing, railway, highway, municipal hydraulic, sanitary, water works, bridge, agricultural, illuminating, heating, ventilating, refrigerating, safety, radio, fire protection, automotive, industrial, military, marine, naval and chemical engineers, and architects, naval architects, chemists and geologists. These branches of engineering and allied sciences cover the whole range of activity in this country upon which is dependent its economic success. It has been said that, *everywhere you look you see the work that the engineer has done.*

Formation of The Federated American Engineering Societies. Engineers and allied technologists have been content to perform their work without notoriety. Dating from a period considerably before the war, the engineer was gradually developing class consciousness, and a desire to be of public service. This desire was intensified as a result of the World War and led to the formation of Engineering Council by the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. In the effort of these societies to determine in what way their activities could be improved and rendered of greater value, committees were appointed by each, and these committees in turn appointed Conferees, who met and organized the Joint Conference Committee. As a result of this intensive desire for service, it was the unanimous opinion of the Joint Conference Committee that a comprehensive organization was desirable that could speak for the engineering and allied technical professions wherever engineering experience and technical training are involved, as well as in matters of common concern to these professions. This recommendation was accepted by the constituent societies who authorized the Committee to call, without delay, a conference of representatives of national, local, state, and regional engineering organizations and affiliations for the purpose of bringing into existence the comprehensive organization recommended. The Committee issued a call to 110 engineering and allied technical organizations for the thoroughly representative Organizing Conference of June 3-4, 1920, which has been characterized as the greatest event in the engineering history of this country.

This organizing conference without a dissenting vote, created The Federated American Engineering Societies and authorized the Joint Conference Committee to act as the Ad Interim Committee between its adjournment and the first meeting of its governing body, American Engineering Council.

Publications of the Joint Conference Committee. Immediately following the Conference, the Joint Conference Committee prepared an abstract of the proceedings of the Organizing Conference in Washington, copies of which were mailed to each of the organizations originally invited to participate and to the technical papers. The Committee was instrumental in securing the cooperation of the technical press and

through the courtesy of McGraw-Hill Company, Inc., published and distributed a sixty-four page booklet entitled *Engineers Unite*, setting forth, "The High Spots in the Washington Organizing Conference, June 3-4, 1920, as Reported and Interpreted by the Editors of the Technical Press," in the issues immediately following the Conference. The Committee issued a formal invitation to each organization, originally invited to the Organizing Conference, to become a Charter Member of The Federated American Engineering Societies, and to appoint delegates to the first meeting of American Engineering Council to be held in November of this year.

The Joint Conference Committee also edited and published in pamphlet form, the Constitution and By-Laws of The Federated American Engineering Societies, which have not only been distributed to the organizations invited to participate, but also to the technical press, and to others, and copies are available for general distribution.

The Joint Conference Committee received communications from the participating organizations and others asking for interpretations of the Constitution and By-Laws, or for explanation of matters pertaining to the movement, and as it was of the opinion that there were doubtless many others to whom the same information would be helpful, therefore, decided to issue Bulletins containing the information requested, which would be available to the organizations invited to participate, as well as to the technical press. Including this, nine Bulletins have been issued. These Bulletins first make announcement of Society action in the matter of membership in, and then answer mooted points in connection with, The Federated American Engineering Societies. Abstracts of these Bulletins have appeared in former issues of the JOURNAL.

Bulletin No. 1, issued July 9, announced the application for Charter Membership of the Technical Club of Dallas on June 22; the action at Montreal Canada, June 28-29, of the American Institute of Chemical Engineers in favorably referring to its Council the matter of becoming a Charter Member of The Federated American Engineering Societies; the action by the American Institute of Electrical Engineers at its Annual Convention at White Sulphur Springs, June 30; and the action taken by the Board of Direction of The American Institute of Mining and Metallurgical Engineers on June 25. The Bulletin also pointed out that the organization was not new; that the work of the body will be administered by American Engineering Council. It gave the resolutions adopted by American Engineering Council on June 17, endorsing The Federated American Engineering Societies and American Engineering Council, and authorizing its Executive Committee to proffer, on the part of Council, its services in establishing American Engineering Council.

Bulletin No. 2, issued July 16, emphasized the fact that the organization does deal with the interests of the individual engineer and allied technologist. It again stated that it was not a new organization; indicated how and why the name was selected; explained the basis of representation; showed that The Federated American Engineering Societies was supported by the contributions of Member Societies and that there was no provision for individual dues; pointed out that American Engineering Council is less cumbersome or unworkable than the present Engineering Council and that, further, it has the definite advantage of being more democratic and broader in its scope and membership. The bulletin also showed that the organization was conservatively financed; that it was democratic and not autocratic; and that there was an opportunity for whole-hearted support on the part of each engineer and allied technologist.

Bulletin No. 3, issued July 23, explained the purposes of The Federated American Engineering Societies; indicated what Engineering Council had done and pointed out what the organization would do, in addition to carrying on what Engineering Council was doing, in the advancement of the engineering and allied technical profession.

Bulletin No. 4, issued July 30, gave the story of the organization of The Federated American Engineering Societies in Washington, June 3-4, 1920 as reflected in excerpts from the editorial and other comment in the technical press, as compiled by the Joint Conference Committee.

Bulletin No. 5, issued August 13, announced the formal acceptance by the American Institute of Electrical Engineers of the invitation to be a Charter Member of The Federated American Engineering Societies and the pledging of its hearty cooperation in the work thereof. It explained the representation of local organizations; and pointed out that The Federated American Engineering Societies was already not only in existence but the largest engineering organization in this country. It also explained the membership requirements and showed that The Federated American Engineering Societies with the advantage of the combined prestige of all its Member Societies, will have a greater standing than any individual organization. It showed that the organization was representative and democratic and pointed out that the movement to federate the engineer and allied technologist was again to bear fruit in the formation of the federation of engineers and architects in the State of Minnesota.

Bulletin No. 6, issued August 20, announced the action by the Annual Convention of the American Society of Civil Engineers in Portland on August 10, in directing its Board of Direction to submit at once to letter ballot, the question, "Shall the American Society of Civil Engineers become a Charter Member of The Federated American Engineering Societies?" It also contained an answer to questions that had been propounded, namely, "If Engineering Council is a success, why should the proposed Federation supplant it?" and, "If Engineering Council is a failure, why should the Federation be organized along lines so nearly parallel?" It pointed out lessons to be learned from Engineering Council, showed that the Organizing Conference in its wisdom recognized the successes and the limitations of Engineering Council, and had evolved an organization in which all of these successes would be utilized and opportunity provided for more effective work on behalf of the engineer and allied technologist. It explained what organizations were invited to become Charter Members of The Federated American Engineering Societies and stated that the Joint Conference Committee did not maintain that the list was complete, that there may be other organizations than those on the list, eligible for membership, and that such organizations may make application for membership to the American Engineering Council. It also explained how members of the Executive Board are elected.

Bulletin No. 7, issued August 27, announced the formal acceptance by the Cleveland Engineering Society at its meeting of August 10 of the invitation to become a Charter Member of The Federated American Engineering Societies. This bulletin explained the manner of selecting representatives on American Engineering Council and that there was no way by which an organization could be compelled to elect them by popular vote of its members since under the provisions of the Constitution, each Society was autonomous and one of the fundamental principles in the call for the Organizing Conference in Washington, was the "non-interference with the interrelation with respect to technical matters, and the maintenance of the autonomy, functions and operations of individual organizations." The Joint Conference Committee felt while the election of representatives by direct vote was desirable, it did not consider the question vital at this time to the success of the American Engineering Council. It also explained why the form of organization was satisfactory.

Bulletin No. 8, issued September 3, was devoted to a detailed explanation of the method of financing The Federated American Engineering Societies. It pointed out that if the engineering and allied technical profession is to take its proper place in public affairs it must have some organization that will

act as a medium for the expression of such service, and this organization must be financed; and that each individual engineer and allied technologist should be willing to contribute at least $10.00 per annum for this cause, although on the basis provided. the average per capita contribution would not exceed one-third of this amount.

Bulletin No. 10, which appears in this issue contains the announcement of the first meeting of American Engineering Council and the program therefor. This without qualification will be a meeting of the greatest engineering organization in the world and as such will mark an epoch in the history of the engineering and allied technical professions. The Federated American Engineering Societies already has an aggregate membership greater than that of any other engineering organization in the world. As has been pointed out repeatedly, the question is not whether this organization will come into existence but the number of members it will have; it already is in existence, and the Joint Conference Committee as the Ad Interim Committee representing it is engaged in furnishing the organizations invited to become Charter Members with information and other assistance to enable them to act intelligently on the invitation. From the advices already received, the Committee can state that American Engineering Council will have a greater number of Member Societies than Engineering Council and will also represent a much larger aggregate membership—estimated considerably in excess of 60,000. The meeting of American Engineering Council in November will deal with the future work of the organization and determine the more important problems that should receive immediate attention. These problems will undoubtedly be those which will be the most helpful in rendering service to the community, state and nation.

SALE OF SURPLUS MATERIAL BY U. S. NAVY

The U. S. Navy Department has available a large supply of merchandise for immediate delivery, including cable, lamps, heaters and fixtures; and also an immense quantity of wire, cable, conduit, porcelain, insulators, boxes, generators, motors, etc., to be released in the near future. All of this equipment is new, in absolutely first class condition and in most cases in the original packing. Discounts are being allowed to quantity buyers.

Inquiries may be addressed to Mr. H. C. Hakes, Board of Survey, Appraisal and Sale; Third Naval District, Fleet Supply Base, 29th and 3rd Avenue, Brooklyn, N. Y.

CURRENT ENGINEERING TOPICS

CENSUS OF CENTRAL ELECTRIC LIGHT & POWER STATIONS

The printed report at the Census Bureau on Central Electric Light and Power Stations for 1917 was issued September 7th. This report is a part of a more complete report on the Electrical Industries which covers railways, telephones, telegraphs and municipal electric fire alarm and police signalling systems. Data for the report were obtained during the year 1918 for the fiscal year ending December 31, 1917. It is the most complete and valuable census taken on American Electrical Industries.

A partial census on Central Electric Stations was included in the census of manufacturers of 1890. This included only the State of New York and the City of St. Louis, so that results were not valuable for comparison with later periods. The fourteenth annual report of the Commissioner taken in 1898 was of great interest and significance, because it included 320 of the 460 known municipal plants and something over 25 per cent of the commercial plants then in existence.

The first complete census of electric light and power stations was taken in 1902 and comparative statistics are confined to that year and to the three quinquennial periods following. The same general form of schedule was used in each of these censuses.

The report which has just been issued covers the general development of Central Electric Light and Power Stations of both the steam and hydroelectric type. The general record of primary power equipment with special attention to generating equipment, line equipment and substation equipment is presented. Output and disposal of current are classified. Very comprehensive financial statistics are given with special comparative financial and operating summaries of selected groups of electric stations. Interesting data on employees, salaries and wages are also given.

Special features of this report are tabulations prepared with the idea of making it possible to study the aspects of the efficiency of commercial and municipal plants.

1. Relative amounts of current generated and purchased by commercial and municipal plants.

2. Stations have been grouped according to population of districts so as to show the density of surface for both light and power.

3. Groups of plants are taken to show the relative investments in electric stations per installed kilowatt capacity for both steam and hydroelectric plants, as well as for plants using gas and oil.

4. Selection and grouping of plants generating current by means of steam, water, gas and oil have been made to show the relative financial and physical efficiency of operation. For this purpose, plants are grouped according to quantity of current which they generate and according to their own use, whether commercial or municipal.

5. A comparison is made of several of the more important plants which purchase their current with those that generate their current. More particularly typical plants which generate no current have been grouped according to the amount of their output so that the relative efficiency of size and ownership can be studied.

VENTILATION OF VEHICULAR TUNNELS

Over a year ago the Bureau of Mines was asked by several of the Eastern cities to cooperate in a study of the effect of exhaust gases from automobiles in long tunnels. At that time Congress would not allow an appropriation for such work. It is believed that the next Congress, however, will give more attention to this subject and may be induced to make appropriations for the study of the whole matter of ventilation during construction and operation of tunnels, as well as making such appropriations as will permit of the study of gases in tunnels. It has become increasingly apparent that the increased amount of oxygen in compressed air causes a big fire hazard; therefore this phase of tunnel construction should be the subject of Government study. The Government, and especially the Bureau of Mines, is in a better position to gather the necessary data than any other agency.

There is an ever increasing amount of tunnel construction in the States—especially in the larger cities— the biggest project at the present time being the New York-Jersey City Tunnel. One of the other big tunnel projects at present under consideration is the six-mile double Moffat tunnel in Colorado which will permit the Moffat Railroad to go into Salt Lake City without encountering the otherwise prohibitive grades.

ENGINEERING FOUNDATION

RELATIONS, POLICY AND WORK

A. Why is engineering Foundation?

Because of need for research, other than researches of Government and large corporations, beyond the means of individual engineers, small companies and separate societies.

B. What has Engineering Foundation?

Endowment of $300,000, assurance of $250,000 more, an or-

ganization based on National engineering societies, and means for publicity.

C. What can Engineering Foundation do?

Receive and administer funds; support researches by individuals or organizations; establish and operate research laboratories; aid in applying to engineering results of research in the sciences; stimulate interest among engineers and the industries, and enlist support.

D. What are Engineering Foundation's relations to

(1) The Engineering Societies?

Joint agency for research; liaison with scientists, through National Research Council. Although the endowment is owned by United Engineering Society for its four founder Societies, the income is to be used "for the furtherance of research in science and engineering or for the advancement in any manner of the profession of engineering and the good of mankind".

(2) National Research Council?

Coöperation in stimulating and coordinating research by governmental, educational, industrial and private agencies.

(3) Division of Engineering, N. R. C.?

According to the "Organization" of N. R. C., the purpose of the Division may be stated: "To promote research and the application of the sciences to engineering". Engineering Foundation may use its funds "in any manner, for the furtherance of research in science and engineering". Therefore, Engineering Foundation may undertake any kind of work which the Division may undertake and others besides. Confusion can be avoided through the intimate relation between Foundation and Council and frequent communication between the officers of the Foundation and the Division. Even in their common field there is work enough for both: By agreement upon program from time to time, interferences will be escaped. The peculiar value of the Division arises from its being an integral part of National Research Council, the national federation of scientists and engineers for the promotion of research, and therefore being in a position to place before scientists engineering problems requiring scientific research and to inform engineers of activities of scientists which may affect engineering. Engineering Foundation can contribute to the support of the Division, can share in its deliberations through interlocking membership, can benefit from its work, and can have its advice as to researches which may profitably be supported by the Foundation. Independently, the Foundation may establish and maintain laboratories, support or conduct researches, and contribute results to the engineering societies. Foundation and Division each is essential to the engineering profession for purposes of research, but the activities of the two must always harmonize.

(4) Scientific Bureaus of Government?

Exchange information; make more available to engineers results of researches by bureaus; suggest to bureaus how to make their researches more helpful.

(5) Consulting and Industrial Laboratories?

Cooperation to make available to them results of research by Foundation and societies, and to obtain for general use, results of their researches.

(6) Engineering Societies Library?

Aid in making this library the repository of all information about research relative to engineering.

E. What needs can Engineering Foundation supply better than any other organization?

Direction and support of research relative to engineering, of such nature as not to be undertaken by an industrial corporation, the Government, nor a university; collection and publication of information about research of particular interest to engineers, utilizing engineering journals.

F. Should Engineering Foundation establish an Engineering Research Institute and Laboratory?

Yes: to supplement the university training of prominent research men; to provide place and means for research by engineers and inventors and for limited cooperative research for industries. The laboratory might be made partially self-sustaining. For some kinds of work or training, charges might be made, particularly for those not of general interest, and for those from which profits will be realized. An establishment under Engineering Foundation would have an independence and celerity of action not feasible in a governmental laboratory and would be able to conduct researches on a scale and in an atmosphere of practical requirements not possible in a university. In the course of years, there might be more than one laboratory, each situated where it would have the best conditions and be most useful.

G. What are Engineering Foundation's needs?

Immediately, a half-million dollars, and, as its work develops, further additions to endowment; funds for establishment and maintenance of an engineering research institute and laboratory.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

OPPORTUNITIES

THE UNITED STATES CIVIL SERVICE COMMISSION announces an open competitive examination for electrical engineering aid. Vacancies in the Bureau of Mines, Department of the Interior, for duty at Pittsburgh, Pa., or elsewhere, at entrance salaries ranging from $1,200 to $1,680 a year, and vacancies in positions requiring similar qualifications at these or higher or lower salaries, will be filled from this examination, unless it is found in the interest of the service to fill any vacancy by reinstatement, transfer, or promotion. On account of the needs of the service applications will be received until further notice. Z-2130.

MECHANICAL ENGINEER with wide experience in industrial plant layout and factory production work. Preferably with experience on steam heating boilers, radiators, etc. Should have good knowledge of conveying equipment. Must also have good experience along production lines and be able to supervise the setting of piece rates, bonus systems, incentives. Location N. Y. City. Z-2095.

SALES ENGINEER FOR ILLUMINATING WORK wanted by large fixture manufacturer having standardized line. Capable aggressive salesman well versed in general illuminating practise. Location New York City. Z-2078.

BOILER DESIGNER AND TROUBLE SHOOTER for large company manufacturing house heating boilers. Experienced men only. Application by letter, giving detail information. Location New York State. Z-2085.

TECHNICAL GRADUATE familiar with electrical equipment in steel mills, who wishes to be associated with the design of this apparatus. State age, technical training and experience. Location Pa. Z-2086.

ELECTRICAL ENGINEER to assist in development of induction and series fan motors. Preference given to man accustomed

to working with detail mechanical apparatus. State age, experience and salary desired. Location Pennsylvania. Z-2056.

Industrial Physician, preferably young man who has had some experience, has a leaning toward that work and a man with enough initiative to organize and supervise department with two or three assistants. Location New York. Z-2057.

Assistant Plant Manager. Must be graduate Mechanical Engineer with a thorough knowledge of Electricity and three to five years experience. Must also be a good executive and able to handle men. The position is with a large bottle company in Ohio. There is a good opportunity for advancement. Man between 30–40 preferred. Location Ohio. Z-2058.

Designer for steam and electric power plants, not a drafting position. Must be able to make calculations on power station design and economics and be a graduate from a high grade technical school. Permanent position. Two men needed. Application by letter only. Location New York City. Z-2044.

General Foreman for boiler shop. Must be man of broad boiler manufacturing experience. Good executive ability, able to direct efforts of two hundred men. Must know boiler details to the last degree. Salary to suit proper man. Location Erie, Pa. Z-2049.

Operating Electrical Engineer for sugar plantations in Cuba. The total kilowatt output of this factory is 1875 at 440 volts. The duties of this engineer would be maintenance and operation and we would be willing to take a bright young man who possibly has been out of school two or three years for this service. Location Cuba. Z-1974.

Boiler Salesman, preferably one handling Horizontal Return Tubular Boilers at present. To work either on salary and commission, or straight commission basis, in the New York market. We have a good opportunity for a thoroughly experienced boiler salesman, one who can get results with a line manufactured to Massachusetts Standard. Location New York. Z-1975.

Salesmen for lubricating oils in foreign fields. Men who are thoroughly familiar with marketing abroad in general, even though they have no lubricating engineering training. Z-1949.

Young Man for meter department, large public utility holdings, offering excellent opportunities for advancement. Applicant must be willing to help out in any department. Man with High School Education preferred. Only men who are reliable and willing to work up need apply. Location Mass. Z-1954.

Assistant Supervisor for printing department of a large corporation. Must have experience in printing technique. and be familiar with office management as work will consist largely of forms, papers, etc., for modern office systems. Age 29 to 40. Location New York State. Z-1875.

Designer, mechanical designer with practical experience on electric switching apparatus. Permanent work for the right man. State age, experience, education and salary expected. Location Pennsylvania. Z-1795.

MEN AVAILABLE

Young Man single, technical education, 6 years experience in Electrical Engineering Work (laboratory, office and construction) desires position offering greater responsibility and future. Location desired, New York or Baltimore districts. Available in one month. E-2343.

Electrical Engineer, technical, 32, married, 8 years experience including design, manufacture, construction and operation. Office and field executive. Location Middle States. Salary $3600 per annum. E-2344.

Electrical and Mechanical Engineer, Indian, age 29, now in India, is desirous of proceeding to America, location New York or vicinity. Eleven years experience in a-c. & d-c. works, steam and hydroelectric power stations, overhead and underground transmission and workshops. Position of responsibility and with consulting or contracting engineers preferred. $5000 and passage found. E-2345.

Graduate Electrical Engineer, (1915) age 27, desires position of greater responsibility with opportunity for advancement. Considerable experience in steam turbines and condensers also all round power plant operation. Three years experience in the testing laboratories of two large public utilities. Available at once. E-2346.

Graduate Electrical Engineer, age 24, single, with 2 years experience in the various phases of electric distribution and construction work. Desires change offering broader opportunities and larger salary. Will consider anything anywhere, offering a real future. E-2347.

Young Man, training, General Electric Company test, desires connection with firm doing commercial engineering for Spanish speaking countries. E-2348.

Electrical Engineer, technical graduate with two years practical experience; including sub-stations and bus car constructions, also transmission line, power house and concrete work. Am experienced in handling men. Desires position where good honest effort is appreciated. Salary $200. E-2349.

Electric Power Expert, 27 years experience on nearly all phases of electric power supply. Have specialized for many years on examination and critical analysis of the financial and engineering sides of existing and proposed undertakings studies of "power market" and of the comparative cost of power production from alternative sources in U. S. and Canada. E-2350.

Electrical Engineer, 36, married. Technical graduate, four years General Electric test, nine years construction, operation and maintenance of transmission lines substations, and steam turbine power plant, and various modern applications, of electricity to the mining of coal. Available on 30 days notice. E-2352.

Engineer, with 22 years practical experience in electrical and mechanical engineering work, age 42, desires engagement on hydroelectric power work in South America. Excellent personality, energetic, first class references. Available on short notice. E-2353.

Executive, resourceful and tactful. Broad engineering and manufacturing experience and familiar with modern business methods. Desire connection with growing concern. Age 36, married, pleasing personality, and in excellent health. Salary at fixed sum or fixed sum and percentage of savings effected. E-2354.

Executive, University education, broad business experience. Industrial Engineering manufacturing, commercial investigations, financial reports, earning, power, cost-engineering, accounting, organization, sales. Available on reasonable notice, for association with firm of manufacturers industrial engineers, accountants, or with high grade banking house. Salary $6000. Prefer salary basis with profit-sharing proportionate to results. E-2355.

Graduate Electrical Engineer, age 32, member A. I. E. E. Extended research and executive experience. Desire position in research or manufacturing. Location no object. E-2356.

Electro-Mechanic; Cornell, 25, four years broad experience including two years G. E. test. Must locate in the immediate vicinity of New York City; desire position requiring good engineering sense and business ability combined with good opportunity for advancement. Small growing concern preferred. E-2357.

Vice President and General Manager, electric, gas, and water properties, 15 years construction, operation and development of small properties. Can prove satisfactory services to stockholders, directors and the public. Desires connection with larger utility or Holding Company. Age 45, married. Present salary $6000. E-2358.

Electrical Engineer, Technically trained, five years experience in circuits, conduit layouts and equipment of central stations and telephone plant desires connection with a manufacturing plant in either an executive or sales capacity. Capable of supervising the electrification of an industrial plant. Vicinity of Philadelphia preferred. E-2359.

Technically Trained Engineer Executive, age 27, single, present manager public service company in city of 10,000 north central west. Experience includes six years construction and operation hydroelectric and steam power plants, transmission lines, etc. Two years officer in Corps of Engineers, U. S. Army. Interested in offer on installation or management project requiring imagination and responsibility in Western United States or Far East. Opportunity most important consideration. Available November 1st. E-2360.

GRADUATE ELECTRICAL ENGINEER, four years experience in telephone and power plant design, construction, and installation, desires connection which will make location abroad imperative. Speaks French. Minimum salary $3,750. E-2361.

TECHNICAL GRADUATE, (E. E.) Nine years in charge of electrical departments for largest industrial incorporations. Nine years chief engineer or assistant engineer on Public Service Commission and valuation work; wishes position as manager or operating superintendent of Public Utility Company or with good company on valuation work. E-2362.

ENGINEER AND EXECUTIVE, desire engagement. Technical graduate, experience, 6 years in electric light and power business as assistant to general superintendent and as division manager, one year in federal employ in responsible capacity operating highly technical gas plant, 1½ years as engineer and chief engineer of large oil corporation, construction of pipe lines, pumping stations, oil loading terminals, etc. E-2263.

CHIEF ELECTRICIAN, 12 years experience on maintenance, construction, installation and testing of all classes of industrial apparatus. Both a-c. and d-c. technical training. Can handle large force of men. Married, age 30. Available at once. Eastern Pennsylvania or New Jersey desired. E-2364.

TECHNICAL GRADUATE, four years laboratory experience in magnetics, thoroughly versed in modern methods of testing electrical steels and materials, desires position with manufacturing concern in need of man with the above training and experience. Salary commensurate with duties and location. Available on reasonable notice to present employer. Married, age 30. E-2365.

OPERATING MANAGER, wishes to negotiate with Public Utility Company. Thorough knowledge in operation of Electrical and Gas properties. Experience twelve years technical engineering and construction; five years operating manager, combination gas and electric plants. Thoroughly versed in rate making and handling municipal and public matters. Salary dependent upon size of properties and location. E-2366.

ELECTRICAL ENGINEER, 31, married. M. E. degree. Nine years experience in public utility work desires connection with consulting or manufacturing firm. Experience in executive, operating and maintenance work, as superintendent and manager, in charge of power plant, distribution system and street railways. Salary $3600. E-2367.

CHIEF ELECTRICIAN OR FOREMEN, 35, good executive, 18 years technical and practical experience a-c. & d-c. stations. Underground distribution and motor work. familiar time study systems. Systematic hustler, natural leader. Desires position in Building—Factory, or Shipyard. Best reference. At present employed. Available on reasonable notice. E-2368.

ELECTRICAL ENGINEER, with university degree and 10 years engineering experience including 2½ years in test and service departments of Westinghouse Electric Company desires a permanent location with chance for advancement. Electric Railway contractor, or public utility in Middle West preferred. Age 30, married. E-2369.

MAGNETIC MATERIALS ENGINEER, desires responsible position concerned with magnetic work, or with electrical laboratory work. Have 10 years experience laboratory measurement in electrical, magnetic, and research work. With G. E. Standardizing Laboratory (Lynn) 3 years; last position 4½ years large magneto company in charge magnetic tests, electrical laboratory, oscillographic work, etc. Thorough technical education; age 34; single; minimum salary $2600; available early part 1921. New York, New England or far west preferred. No subordinate positions considered. E-2370.

ADDRESSES WANTED

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street,

1. James F. Elliott, Electric Controller & Manufacturing Co., Oliver Building, Pittsburgh, Pa.
2. Wilmer K. Graeff, 533 Muriel Parkway, Elizabeth, N. J.
3. Oliver H. Horner, c/o Black & Veatch, 507 Interstate Bldg., Kansas City, Mo.
4. Wilfred Langille, Marion Station, Publice Service Electric Co., Jersey City, N. J.
5. Alex. E. E. Mayo, Carnegie Institute of Technology, Pittsburgh, Pa.
6. P. J. Reese, 7th & Main Street, Royal Oak, Mich.
7. Harry Symes, Lyne Manufacturing Co., Orange, Va.

PERSONAL

A. G. JANES has changed from the Standard Steel Castings Co., Cleveland, Ohio. to become Superintendent of Maintenance with the Interstate Foundry Co., Clearing, Illinois.

ROBERT T. LOZIER of Chicago was married on August 7th at Northport, L. I., to Lucille Scheffler, daughter of Mr. and Mrs. Frederick A. Scheffler.

M. L. HASELTON, formerly with the Westinghouse Electric and Mfg. Co., has accepted a position as Assistant to G. L. Knight, Designing Engineer of the Brooklyn Edison Company, Brooklyn, N. Y.

S. F. SHAW has resigned as Superintendent for the American Smelting and Refining Co., at Charcas, S. L. P. to accept a position as Manager of the Cia, Mra. La Constancia, at Sierra Mojada, Coahuila, Mexico.

GANO DUNN, Past President of the Institute and President of the J. G. White Engineering Corporation was married on August 26th to Mrs. Julia Gardiner Gayley of New York, daughter of the late Curtis Crane Gardiner of Gardiner's Island.

E. A. BROFOS, who has been representing the Western Electric Company in Northern Europe for several years, has been appointed manager of a new Norwegian corporation to handle all of the Scandinavian business of the International Western Electric Company. This will be known as the Western Electric Norsk Aktiesekskap, and its headquarters will be located in Christiania.

OBITUARY

DR. SAMUEL SHELDON, Past President of the American Institute of Electrical Engineers and Professor of Physics and Electrical Engineering for 31 years at The Polytechnic Institute of Brooklyn, died on Saturday evening, September 4th of Brights' disease at the Addison House, Middlebury, Vt. With him at the time of his death were his only son, Samuel Sheldon, Jr., of Brooklyn and his only surviving sister, Mrs. Susan B. Miner of Middlebury. The services and burial took place in Middlebury, where his wife, who was Frances Warner Putnam of Brooklyn, died in 1914.

Dr. Sheldon was born in Middlebury on March 8, 1862, the son of Harmon Alexander and Mary Bass Sheldon. He was graduated from Middlebury College in 1883 with the degree of A. B. and then pursued graduate work, receiving the degree of A. M. in 1886. During the next two years he studied at Wurzburg, Germany, and received the degree of Doctor of Philosophy there in 1888. During a part of this time he was associated with Kohlrausch, the distinguished physicist, in his celebrated determination of the ohm as the unit of electrical resistance. He was awarded the honorary degree of Doctor of Science from the University of Pennsylvania in 1906, and from Middlebury College in 1911.

Dr. Sheldon went to the Polytechnic Institute of Brooklyn in 1889, after a year spent at Harvard as instructor of physics, and was immediately honored with a full professorship in physics and electrical engineering. He was then in his 27th year. His thorough command of his subjects, together with the enthusiasm and energy which he exhibited in the lecture room,

gained for him a reputation as one of the foremost educators in the engineering profession. His strong points as a teacher were his inspiring and sympathetic personality, keen analytical mind, executive and cooperative ability, and tremendous capacity for work. Illness in 1909 necessitated a long vacation, and he chose to spend it in a trip to Europe, where he had an opportunity to visit the principal engineering schools of Germany, the British Isles, France and Italy.

Over 1,000 graduates of the Polytechnic received instruction from Dr. Sheldon and a majority of them held him in such affectionate regard that he was popularly known to them as "Sammy." Many of his former students became men of renown in the engineering world. Among them are Bancroft Gherardi, vice president and chief engineer of the American Telephone and Telegraph Company, and Arthur W. Berresford, President of the American Institute of Electrical Engineers.

Dr. Sheldon was the author and joint author of several college text-books. Among them were "Direct-Current Machines," "Alternating-Current Machinery," "Electric Traction and Transmission Engineering" and "Physical Laboratory Experiments." He had also written a number of monographs and papers on special topics.

Dr. Sheldon was elected an Associate in the A. I. E. E., in 1890 and transferred to Member in 1891, and to Fellow grade in 1913. He was elected President of the Institute for the year 1906-07. During his many years of connection with the Institute, Dr. Sheldon always showed an intense interest in its welfare, and gave unstintedly of his services and advice to the many committees on which he served. From 1898 to 1909 he was a Director of the Institute; from 1902-06, Chairman of the Meetings and Papers Committee; 1908-09, Chairman Standards Committee; 1910, Chairman, Library Committee; on Committee Cooperative Research, 1898-1900. Reception Committee 1900; Local Organizations Committee, 1902-03;. By-laws Committee, 1903-04; Executive Committee 1906-07; Committee on Code of Ethics, 1908-09. Dr. Sheldon represented the Institute on the Committee of International Electrotechnical Commission, 1911-12; the John Fritz Medal Association of which he was Past President; the Joint Committee of the Society for the Promotion of Engineering Education; the American Association for the Advancement of Science; the International Congress of Applied Chemistry. He became a Trustee of the United Engineering Society, representing the Institute, in 1916. He was elected its Assistant-Treasurer in that year and held that office until his death. He was Chairman of the Library Board for 1915-16 and Vice Chairman for the current year. At the time of his death Dr. Sheldon was also a member of the Committee on Geographical Divisions and Electric Procedure and Chairman of the Law Committee.

Among other activities with which Dr. Sheldon was connected might be mentioned: New York Electrical Society (Past President); American Physical Society; American Electrochemical Society (Past Manager); National Electric Light Association; Interurban Street Railway Association.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES AUGUST 1-31, 1920.

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

CORRECTION.

The price of "Graphic Production Control" by C. E. Knoeppel, is $10.

WIRING FOR LIGHT AND POWER.

A Detailed and Fully Illustrated Commentary on the National Electrical Code. By Terrell Croft. Second edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 465 pp., illus., tables, 8 x 5 in., flexible cloth, $3.

The purpose of this book is to supply explanations, elaborations and illustrations for those sections of the National Electrical Code to which most frequent reference is necessary. For this purpose the most important Code regulations are given verbatim, and their application in practical electrical construction is explained by supplementary text and drawings. This edition has been fully revised to correspond with the 1918 edition of the Code.

ACCOUNTS IN THEORY AND PRACTISE. PRINCIPLES.

By Earl A. Saliers. First edition. N. Y. and London McGraw-Hill Book Co., Inc., 1920. 301 pp., 9 x 6 in., cloth, $3.

CONTENTS: Fundamental Principles; Partnership Accounting; Expansion of Accounting Records; Corporation Accounting; Financial Statements; Special Application of Principles.

This volume, by an assistant professor of accounting in the Sheffield Scientific School is intended as an introduction to the principles of accounts. An attempt has been made to attain an effective combination of theoretical discussion and practical application. Bibliographies are given with each section of the book.

ANALYSIS OF PAINT VEHICLES, JAPANS AND VARNISHES.

By Clifford Dyer Holley. N. Y., John Wiley and Sons, Inc.; Lond., Chapman and Hall, Ltd., 1920. 203 pp., illus., tables, 8 x 6 in., cloth, $2.50.

The author, an experienced paint chemist, presents the methods used in his laboratory for the systematic examination of paint vehicles.

THE BUSINESS MAN AND HIS BANK.

By William H. Kniffin. First edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 278 pp., illus., 8 x 6 in., cloth, $3.

This volume treats banking from the viewpoint of the customer and is intended to assist the business man to that knowledge

which will enable him to select his bank, to make proper use of it and to understand the ways in which it can aid him in his business.

A COURSE IN ELECTRICAL ENGINEERING.

Volume 1. Direct Currents. By Chester L. Dawes. First edition. N. Y., and London, McGraw-Hill Book Co., Inc., 1920. 496 pp., illus., 8 x 6 in., cloth, $4.

The present book is the first of two volumes which are intended to serve as a comprehensive text covering the general field of electrical engineering in a simple manner. It will be useful, the author believes, to students of electrical engineering as an introduction to more advanced texts and also to students who are studying the subject for general training, without the intention of becoming specialists. The treatment is detailed, straightforward and systematic, but avoids much mathematical analysis.

THE DESIGN OF HIGHWAY BRIDGES OF STEEL, TIMBER AND CONCRETE.

By Milo S. Ketchum. Second edition rewritten. N. Y., McGraw-Hill Book Co., Inc.; London, Hill Publishing Co., 1920. 548 pp., illus., diagrams, charts, tables, 9 x 6 in., flexible cloth, $6.

This new edition has been made necessary by the increase in live loads due to the extensive use of heavy motor trucks and tractors, and the increased use of reinforced concrete in highway bridge construction. The scope of the book has been extended to include the design of concrete and timber bridges as well as steel bridges. The discussion covers all the details of constructing highway bridges. This edition is uniform with the author's "Structural Engineers' Handbook."

DREDGING ENGINEERING.

By F. Lester Simon. First edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 182 pp., illus., plate, tables, 9 x 6 in., cloth, $2.50.

The author of this volume has attempted to supply a work which will describe the principal types of dredges in such a manner as to impart a fundamental working knowledge of their construction and operation, He also takes up concisely the problems that confront the engineer in the conception and accomplishment of dredging projects.

EARTHWORK AND ITS COST.

A Handbook of Earth Excavation. By Halbert Powers Gillette. Third edition. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1920. 1346 pp., illus., tables, 7 x 5 in., flexible cloth, $6.

This treatise covers systematically and comprehensively the methods of excavating for engineering work of all kinds. In addition to the results of his own experience, the author has included a summary of the material in American technical literature. Particular attention is given to cost data. The present edition has been revised.

FLUGTECHNIK: GRUNDLAGEN DES KUNSTFLUGES.

By Arthur Pröll. München and Berlin, R. Oldenbourg, 1919. 332 pp., illus., 9 x 12 in., paper, 30.25 marks (33 marks, bound).

This treatise is founded on manual of the scientific foundations of the subject, prepared for practical self-instruction, while the author was director of the aeronautical experiment station of the Austrian war ministry. The notes prepared for this purpose were used later in connection with his lectures on technical aerodynamics in the Hannover High School, from which the present work has been prepared. The book, therefore, presents the subject from the viewpoint of immediate practical usefulness and also emphasizes the connection of aeronautical calculations with the teachings of mechanics. It will serve, the author believes, not only as a text for students, but will also enable the experienced engineer to carry out designs and construction in all details, when combined with practical numerical data. The discussion is confined to monoplanes and biplanes of the usual type.

HENLEY'S TWENTIETH CENTURY FORMULAS, RECIPES AND PROCESSES.

Containing Ten Thousand Selected Household and Workshop Formulas, Recipes, Processes and Money-saving Methods for the Practical Use of Manufacturers, Mechanics, Housekeepers and Home Workers.

Edited by Gardner D. Hiscox. 1920 edition, revised and enlarged, N. Y., The Norman W. Henley Publishing Co., 1920. 807 pp., 9 x 6 in., cloth, $5.

The formulas in this volume cover a wide range of manufactures and operations. They have been collected from a variety of sources, special attention having been paid to foreign publications not usually available. In this edition the work has been modernized.

HOW TO MANAGE MEN.

The Principles of Employing labor. By E. H. Fish. N. Y., The Engineering Magazine Co., 1920. 337 pp., 9 x 6 in., cloth, $5.

This book is a discussion of the relations between workers and their employers, in which an attempt is made to evaluate the things that go to make a satisfactory working organization. The author discusses the establishment of an employment department, the problems of the employment manager, the promotion of industrial relations, and industrial education.

THE IRON AND STEEL INDUSTRY OF THE UNITED KINGDOM UNDER WAR CONDITIONS.

A Record of the Work of the Iron and Steel Production Department of the Ministry of Munitions. By F. H. Hatch. London, privately printed for Sir John Hunter by Harrison and Sons, 1919. 167 pp., illus., plates, portraits, charts, tables, 10 x 6 in., cloth, (gift of author).

This volume is an interesting account of the methods used by the British Government to obtain the necessary increase in the steel production of Great Britain during the war. The vastness of the field covered, the variety and complexity of the technical problems involved and the far-reaching industrial questions raised, made the subject one of great interest and importance.

MACRAE'S BLUE BOOK.

Chicago and N. Y., MacRae's Blue Book Co., 1920. 1853 pp., 11 x 9 in., cloth, $10.

An alphabetically arranged directory of American manufacturers, which is especially full with respect to iron and steel products, and the materials used by railways and in building. In addition to the directory of materials, it contains a list of addresses, and also of trade names, a standard list of prices and a collection of data used by buyers. Thirty thousand firms are included.

MARINE ENGINEERS' HANDBOOK.

Prepared by a staff of specialists, Frank Ward Sterling, Editor-in-Chief. First edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 1486 pp., illus., tables, 7 x 5 in., flexible cloth, $7.

This handbook is compiled for the use of operating and designing engineers, and students. To cover the main subjects and the many ramifications of marine engineering, it has been necessary to enlist the services of thirty specialists, each of whom has received the hearty cooperation of others in the same field. The best endeavor has been made to coordinate different practises in order that all data may be reliable and unbiassed. The handbook is a pioneer in its field.

MATHEMATICS FOR ENGINEERS.

Part II. By W. N. Rose. N.Y., E. P. Dutton and Co., 1920. 419 pp., illus., tables, 9 x 6 in., cloth, $7.

The work of which this is the second volume is intended to occupy a position midway between those written for college students, which are usually academic in character, and those practical books which omit any discussion of the scientific basis underlying them. It is intended to contain all the mathematical work needed by engineers in their practice and by students of all branches of engineering. This volume treats of the differential and integral calculus, spherical trigonometry and mathematical probability.

MINE BOOKKEEPING.

A Comprehensive System of Records and Account for Mining Operations of Moderate Dimensions. By Robert McGarraugh. First edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 118 pp., illus., 9 x 6 in., cloth, $2.

This discussion of mine accounting is intended to show a system of records and accounts adequate for small mines, where the elaborate systems necessary for large-scale operations would require too large a clerical staff.

PERSONNEL ADMINISTRATION.

Its Principles and Practise. By Ordway Tead and Henry C. Metcalf. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1920. 538 pp., 9 x 6 in., cloth, $5.

The purpose of this book is to set forth the principles and the best prevailing practise in the field of the administration of human relations in industry. It is addressed to employers, personnel executives, employment managers and students of personnel administration, but will have value, the authors hope, also for all who are interested in advancing right human relations in industry and in securing a productivity that is due to willing human cooperation, interest and creative power. The field covered includes those efforts usually included in personnel management: employment, health, and safety, training, personnel relations, service features and joint relations. The book also seeks to show the relation of the personnel problems of each corporation to those of its industry as a whole, by considering the activities of employers' associations and organizations of workers.

RAILROAD CURVES AND EARTHWORK.

By C. Frank Allen. Sixth edition, revised. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 289 pp., diagrams, charts, tables, 7 x 4 in., flexible cloth, $4.

This book has been prepared for the use of the students in the author's classes at the Massachusetts Institute of Technology, but it will also, he believes, be useful to engineers who have to deal with earthwork computation or curves.

The new edition is marked by an extension of the treatment of circular arcs; by new methods for the computation of earthwork, additional data on haul, and by general revision.

SHOP PRACTISE FOR HOME MECHANICS.

Use of Tools: Shop Practises: Construction of Small Machines. By Raymond Francis Yates. N. Y., The Norman W. Henley Publishing Co., 1920. 320 pp., illus., 9 x 6 in., cloth, $3.

The author's object has been to prepare a handy reference book for the amateur mechanic which would give processes that could be employed without elaborate equipment or great expense.

STEAM SHOVEL MINING.

Including a Consideration of Electric Shovels and other Power Excavators in Open-pit Mining. By Robert Marsh, Jr. First edition. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 258 pp., illus., tables, 9 x 6 in., cloth, $3.50.

The purpose of this volume is to present general information upon the development and study of those mining problems which may best be solved by open-pit methods involving the use of power excavators. A general knowledge of mining practise is assumed.

STRUCTURAL STEELWORK.

Relating Principally to the Construction of Steel-framed Buildings. By Ernest G. Beck. London and New York, Longmans, Green and Co., 1920. 462 pp., illus., tables, 9 x 6 in., cloth, $7.50.

This book presents information likely to be of use in the design and construction of ordinary steel-framed structures. The principal endeavor has been to be broadly suggestive, rather than particular or exhaustive, to propose common sense lines of argument based upon straightforward consideration of the facts, instead of attempting to generalize or formulate specific relations from details which cannot be more than typical. The work follows British practise, and is based upon a series of articles contributed to the Mechanical World.

SURVEYING.

By W. Norman Thomas. London, Edward Arnold, 1920. 537 pp., illus., plate, maps, tables, 9 x 6 in., cloth, $10.50. (Gift of Longmans, Green and Co.)

CONTENTS: Chain Surveying; Optics and Magnetism; Instruments; The Theodolite; Theodolite Surveying and Dialling; The Level and Levelling; Trigonometrical and Barometrical Levelling; Tacheometry and Rangefinding; Plane Table Surveying; Curve Ranging; Earthwork Calculations; Hydrographic Surveying; Triangulation; Base Line Measurement; Spherical Trigonometry; Astronomical Terms; Meridian, Longitude, Latitude and Time; Photographic Surveying; Appendix:—Errors in Surveying; Trigonometrical Formulas; Miscellaneous Examples.

The author of this treatise is Lecturer in civil engineering in the University of Birmingham, England, and the volume is an amplification of his lectures to students. It is intended as a textbook and a reference book for surveyors in practise. Calculus is used where necessary, and a special effort has been made to keep the investigation of errors before the readers' mind.

TECHNICAL GAS AND FUEL ANALYSIS.

By Alfred H. White. Second edition, revised and enlarged. N. Y. and London, McGraw-Hill Book Co., Inc., 1920. 319 pp., illus., tables, 8 x 6 in., cloth, $3.

The first edition of this work, which appeared in 1913, was intended to present the conclusions of the various committees of technical societies which had reported on the testing of fuels and their utilization. Since 1913 our knowledge of gas and fuel analysis has been distinctly increased. Standard methods for sampling and analyzing coal and coke and for examining liquid fuels have been adopted by several societies. Methods for gas analysis have been critically studied and new methods developed. These advances have been carefully reviewed for this edition, which is about 20 per cent larger than the former one.

TEXTBOOK OF AERO ENGINES.

By E. H. Sherbondy and G. Douglas Wardrop. N. Y., Frederick A. Stokes Co., copyright 1920. 363 pp., illus., diagrams, plates, 12 x 9 in., cloth, $10.

The present work is a review of the theory and practise of the design of engines for aerial navigation. The first part treats of theory and includes the theory of the cycle, the work available, the effect of altitude, pressure, etc., on the power, and the theory and design of compressors. The second part describes the current types of American, British, French, German and Italian engines. An appendix gives tables of use to designers. The book is fully illustrated with drawings and photographs.

UTILISATION DES VAPEURS D'ECHAPPEMENT DANS LES HOUILLERES.

en Vue de la Production d'Energie Electrique. By Adrien Barjou, preface by Maurice Soubrier. Paris, Gauthier-Villars et Cie, 1920. 90 pp., illus., 10 x 6 in., paper.

The author of this work discusses the utilization of exhaust steam in low-pressure turbines for the production of electricity or compressed air. The particular case studied is that of coal mines which have outgrown their power-plants and are faced with the necessity of extending them. The economic and technical results obtained with low-pressure turbines are set forth in this book.

VOCATIONAL ARITHMETIC.

By Clarence E. Paddock and Edward E. Holton. N. Y. and Lond., D. Appleton and Co., 1920. 232 pp., illus., tables, 7 x 5 in., cloth, $2.

This is an elementary arithmetic for vocational schools anp mechanics, in which the usual branches of arithmetic are treated in a simple way and accompanied by a large number of practical problems, carefully selected to present applications to sucq vocations as shopwork, carpentry, masonry, foundry work and excavation.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Atlanta.—July 29, 1920, Atlanta Gas & Electric Building. Business meeting. Election of officers as follows: Chairman, H. L. Wills; Vice-Chairman, H. E. Bussey; Secretary-Treasurer, J. M. Bradfield; Executive Committee, G. A. Iler, J. E. Mellett and Geo. K. Selden. Attendance 29.

August 26, 1920, Atlanta Gas & Electric Building. Business meeting. Attendance 23.

Cincinnati.—September 9, 1920, Assembly Hall, Union Gas & Elec. Company. The speaker of the evening was Mr. P. M. Lincoln, a Past-President of the Institute, who gave a very interesting talk on the history of the Institute, especially that part which refers to Sections. The second part of Mr. Lincoln's program was on the electrification of steam roads. He enumerated the different steam roads that had already been electrified, and gave figures proving how the electrification of steam roads would benefit the entire country. Attendance 53.

Denver.—August 19, 1920. Savoy Hotel. This special meeting was called in honor of Secretary Hutchinson, who visited Denver on his return trip from the Pacific Coast Convention. Mr. Hutchinson talked to the members about Institute affairs in general and particularly about some of the new features in organization which were under consideration. Mr. H. B. Dwight was called upon and told something of his experiences at the Annual Convention where he went as a representative of the Denver Section. Attendance 18.

Detroit-Ann Arbor.—August 23, 1920. Meeting of Executive Committee for the purpose of appointing various committees of the Section. Present: Messrs. Parker, Kittredge, Albright, Reyneau, Meyer, Cannon and Wise.

Spokane.—August 9, 1920, W. W. P. Co. Meeting of Executive Committee. Appointment of Mr. H. V. Carpenter as Vice-Chairman in place of Mr. Foster Russell, resigned. Appointment of Mr. Royer as Chairman of the Membership Committee and Mr. Henderson as Chairman of the Papers Committee Present: Messrs. Daniels, Fisken, Royer, Henderson, Pospisil.

Utah.—August 16, 1920, Commercial Club. Speaker: Mr. F. L. Hutchinson, Secretary of the Institute. Subject: "Institute Activities." Attendance 16.

Prior to the meeting a dinner was held for Mr. Hutchinson at the University Club, at which 12 members of the Section were present.

August 23, 1920, Commercial Club. Meeting of Executive Committee. Resignation of Mr. H. D. Randall as member of Executive Committee accepted and Mr. C. P. Kahler elected in his place. Mr. D. L. Brundige appointed Chairman of Program Committee. Secretary instructed to ask Board of Directors of Institute for extension of Section territory. Present: Messrs. Merrill, Ashworth, Brundige, Plumb and Talmage.

PAST BRANCH MEETING

University of California.—August 25, 1920. Talk on "Westinghouse Junior Courses" by Messrs. Andrews, Baston and Cates. Attendance 11.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 31, 1920.

Allis, Selden P., Chicago, Illinois
Armistead, Frederick V., Schenectady, N. Y.
Babcock, Courtlandt W., Boston, Mass.
Baker, Harry G., Tooele, Utah
Bell, Hugh G., E. Pittsburgh, Pa.
Boone, Frank P., Peoria, Ill.
Boyd, Wilfred R., Erie, Pa.
Bradley, Herbert E., New York, N. Y.
Brettle, Arthur C., Buffalo, N. Y.
Brewer, Aubrey, Tapoco, N. C.
Buell, Harry C., Saginaw, Mich.
Chamberlin, Robert F., Ithaca, N. Y.
Clarke, Arnim R., Toronto, Ont.
Conaway, Ralph A., Atlanta, Ga.
Conesa, Julius M., Peekskill, N. Y.
Creamer, Walter, Jr., Orono, Maine
Cross, Gordon F., Toronto, Ont.
DeMott, George L., Arlington, Va.
Drake, Chester W., E. Pittsburgh, Pa.
Dressler, Alfred F., New York, N. Y.
Feely, John J, Brooklyn, N. Y.
Frizzell, Lionel K., Glace Bay, N. S.
Gartner, C. K., Brooklyn, N. Y.
Graham, H. L., Jenkins, Ky.
Hastings, John LeR., Bozeman, Mont.
Hayne, John, Hanover, Ont.
Herlitr, Ivar, Cambridge, Mass.
Hobart, Karl E., (Member), Chicago, Ill.
Hoch, Ellery T., New York, N. Y.
Holderness, H. C., Pittsfield, Mass.
Huang, Tuh Siu, New York, N. Y.
Hudson, E. L., Harrisburg, Ill.
Jackson, John B., Chicago, Illinois
Keiser, Morris, Washington, D. C.
Knierim, Gustave J., Astoria, L. I., N. Y.
Lauthers, James P., Fort Andrews, Mass.
Leahy, Joseph A., St. Louis, Mo.
Luther Geo. D., Seattle, Wash.
Mock, Frank C., Schenectady, N. Y.
Mongan, Hugh B., Hagerstown, Md.
Moore, George M., Lamar, Colo.
Moulton-Redwood, M. J., Toronto, Ont.
Murdoch, Kenneth B, Harrison, N. J.
Nishi, Takeshi, New York, N. Y.
Noell, John J, (Member), Wilmington, Del.
Odajima, Shuzo, New York, N. Y.
O'Regan, Stephen P., Port Richmond, StatenIsland, N. Y.

Pagliarulo, Vincent, (Member), Beloit, Wis.
Parra, Albert R., New York, N. Y.
Patterson, G. R., Pittsburgh, Pa.
Peeples, Richard G., (Member), Phoenix, Ariz.
Pembleton, Fred W., Ft. Wayne, Ind.
Phillip, Harry J., Brewster, Fla.
Platt, Albert H., Bridgeport, Conn.
Pradhan, S. R., Lynn, Mass.
Reyes, Salustiano, Washington, D. C.
Roberts, George W., Lynn, Mass.
Romano, Michael, Schenectady, N. Y.
Roselle, Henry, Cedar Rapids, Iowa
Rudolph, Lothar E., Omaha, Neb.
Schell, Leroy S., Jr., Pittsfield, Mass.
Schiff, Martin, (Member), Chicago, Ill.
Schrade, W. A., Waco, Texas
Seaman, Wm. E., New York, N. Y.
Sels, Hollis K., Pittsburgh, Pa.
Sisler, C. O., Sault Ste Marie, Ont.
Smith, Floyd T., Schenectady, N. Y.
Smith, Merrill J., Boston, Mass.
Stites, Samuel, Schenectady, N. Y.
Strong, Elmer E., (Member), Syracuse, N. Y.
Sullivan, James D., Tucson, Ariz.
Taylor, H. L., Vancouver, B. C.
Travi, John J., Philadelphia, Pa.
Treadwell, Leon H., Worcester, Mass.
Tyne, Gerald F. J., Troy, N. Y.
Umstead, A. O., Big Stone Gap, Va.
Van Ness, Neil T., Takoma Park, D. C.
Viall, Ethan, (Member), New York, N. Y.
Welch, Leo T., Albany, N. Y.
Wenk, Roy, E., Seattle, Wash.
Westervelt, H. M., East Orange, N. J.
Whiteman, W. S., Atlanta, Ga.
Wright, M. C., Newark, N. J.
Young, Willis M., Wenona, Ill.

Total 85.

Foreign

Araujo, Cauby, Rio de Janeiro, Brazil, S. A.
Campanari, E., Milan, Italy.
Chang, Ting Chin, (Member), Shanghai, China
Crisp, Miles H. T., Oorgaum, Kolar Gold Field, S. India
Culleto, Leo G. (Member), London, England
Doyen, Daniel, Paris, France
Fuller, James C., (Member), Perak, Federated Malay States
Innes, William A., Christchurch, N. Z.
Miyahara, Nobuhide, Tokio, Japan.
Protheroe, Roderick, N. L., Estado de Minas, Brazil, S. A.
Sinclair, William J., Gisborne, N. Z.
Val Davies, A. E., (Member) Cape Town, S. Africa

Total 12.

OFFICERS of A. I. E. E. 1920-1921

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FRANK JULIAN SPRAGUE, 1892-3.	GANO DUNN, 1911-12.
*EDWIN J. HOUSTON, 1893-4-5.	RALPH D. MERSHON, 1912-13.
*LOUIS DUNCAN, 1895-6-7.	C. O. MAILLOUX, 1913-14.
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CARL HERING, 1900-1.	H. W. BUCK, 1916-17.
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CHARLES F. SCOTT, 1902-3.	COMFORT A. ADAMS, 1918-19.
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*Deceased.

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Lightning Arrester Spark Gaps—II

BY CHESTER T. ALLCUTT
Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

This paper presents data giving the discharge characteristics of a commercial type of impulse gap under different conditions. Test data are also presented giving the characteristics of certain experimental gap structures designed to minimize the effects of adverse weather conditions, such as rain, fog, etc. A brief discussion of some of the factors that determine the degree of protection afforded by a lightning arrester spark gap is included in the paper. The term "protection factor" is defined and curves giving the protection factor of certain types of gap are presented.

IN a former paper presented before the American Institute of Electrical Engineers in June 1918,[1] the writer described a selective gap for lightning arresters and gave the results of a number of tests on an experimental form of such a gap. Since the presentation of that paper, this selective gap, now commonly known as the impulse gap, has gone into rather extensive commercial use and it is thought that some data concerning the electrical characteristics of the commercial form of gap might be of interest. The object of this paper is to present such data and to discuss some of the features upon which the protective value of the gap depends.

It is well-known that the danger to electrical apparatus due to line disturbances of steep wave-front may be all out of proportion to the actual voltage of the disturbances. This is because a voltage of high frequency or of steep wave-front does not distribute itself uniformly through an electrical winding, but tends to "pile up" on the end turns of the winding and thus greatly endanger the insulation between turns. Due to its high electrostatic capacity the electrolytic lightning arrester is particularly well adapted to discharge high-frequency disturbances. Unfortunately, the electrolytic arrester must be connected to a line through a spark gap, as permanent connection to the line will result in over-heating and ultimate destruction of the arrester. It is necessary that the spark gap which connects the arrester to the line be so adjusted that it will not discharge normal line voltage. It is highly desirable, however, that the spark gap should discharge high-frequency disturbances at the lowest possible voltage in order to obtain a high degree of protection against such dangerous disturbances. The value of the impulse gap lies in the fact that it is selective in its action, that is, it will discharge a high-frequency disturbance at a voltage considerably less than its 60-cycle discharge voltage. By means of this gap, an electrolytic arrester may be isolated from the line under normal conditions and yet is automatically connected to the line upon the occurrence of a high-frequency impulse even if the magnitude of this impulse is less than the 60-cycle setting of the gap.

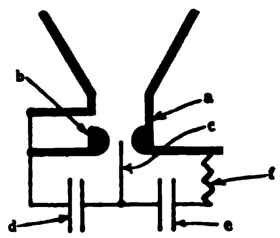

FIG. 1—DIAGRAM OF IMPULSE GAP

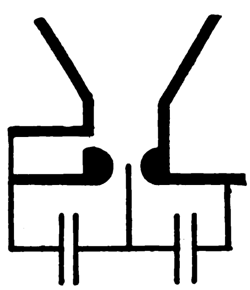

FIG. 2A—IMPULSE GAP ON 60 CYCLES

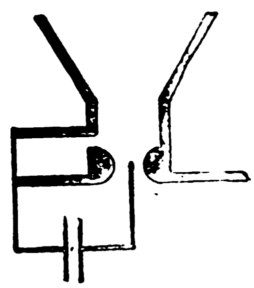

FIG. 2B—IMPULSE GAP WITH HIGH FREQUENCY APPLIED

Fig. 1 shows the electrical circuits involved in the simplest form of impulse gap. The gap proper consists of two sphere-horn electrodes *a* and *b*, which are connected respectively to the line and to an electrolytic arrester in the usual manner. In addition to these two main electrodes, an auxiliary electrode *c* is provided which is connected to one of the horns through a condenser *d* and to the other horn through a similar condenser *e* and a high resistance *f*. When a 60-cycle-

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1. C. T. Allcutt, "Lightning Arrester Spark Gaps." TRANSACTIONS, A. I. E. E., Volume XXXVII.

e. m. f. is applied across the gap the impedance of the resistance is negligible compared with that of the condensers, so the circuit is equivalent to that shown in Fig. 2A. In this figure, it will be seen that if the two condensers are equal, the potential of the auxiliary electrode will be half-way between the potentials of the two main electrodes. If the auxiliary electrode is placed half-way between the main electrodes, it will have practically no influence on the distribution on the electrostatic field between the two main electrodes, and consequently, the voltage required to produce a discharge across the gap will be substantially unaltered by the presence of the auxiliary electrode. If a high-frequency e. m. f., such as a line disturbance of steep wave-front, is impressed on the gap, conditions will be quite different from those existing when a 60-cycle e. m. f. is applied. In this latter case, the impedance offered by the resistance element is very much greater than the impedance of the condensers, so that the gap becomes very nearly equivalent to that shown in Fig. 2B. In this case it will be seen that if the capacity of the condenser is large compared with the capacity existing between the auxiliary electrode and the main electrode, practically the entire voltage will appear across half the gap, that is, between the auxiliary electrode and one of the main electrodes. A discharge across this half gap will immediately charge up the condenser to full voltage and a discharge across the other half of the gap will immediately follow. It becomes apparent from the foregoing that the discharge voltage of the gap should be much lower when a high-frequency e. m. f. is applied than when 60-cycle e. m. f. is applied. For example, if we assume that the separation between the main electrodes is, say, six cm., the gap will behave on a 60-cycle line in the same manner as an ordinary sphere horn gap having the same gap setting. When a high-frequency e. m. f. is applied to the gap, it will be very nearly equivalent to a needle gap having a setting of but three cm. As pointed out in the writer's former paper, it has actually been demonstrated by experiment that this construction does result in a much lower discharge voltage for high frequency than for 60 cycles.

Fig. 3 shows a standard 44,000-volt impulse gap. A rather exhaustive series of experiments was carried out on the gap shown in this photograph. The experiments involved tests on frequencies ranging from 60 cycles up to the highest frequencies that could be produced in the laboratory. Inasmuch as the other sizes of impulse gaps have characteristics very similar to those of the one shown, the writer is presenting here only the data obtained on this one size of gap, because the most complete series of tests was made on this size.

The gap shown in Fig. 3 differs somewhat from the experimental type described in the previous paper. The capacitances for maintaining the auxiliary electrode at the proper potentials are furnished by pin type insulators *a* and *b*. These insulators have an electrostatic capacity of approximately 2×10^{-11} farad. Due to the effect of capacity to ground, the auxiliary electrode is not maintained at a potential exactly half-way between the potentials of the main electrodes. It has been found by experiment that the proper position of the auxiliary electrode is such that its distance from the

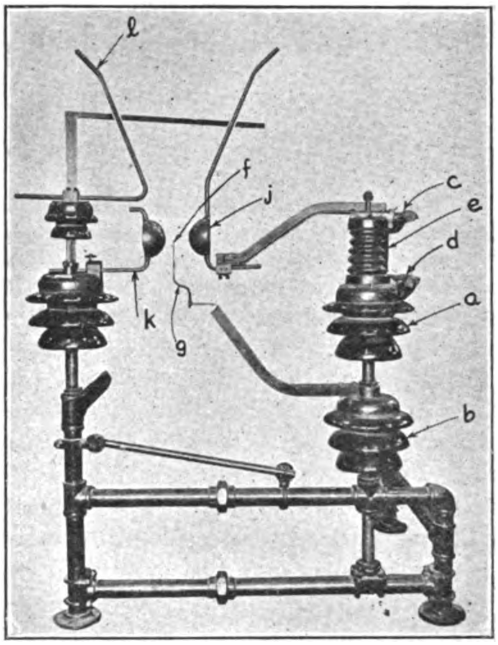

FIG. 3—44,000-VOLT IMPULSE GAP

sphere horn *m* is approximately six-tenths of the gap length. In this position it does not materially alter the 60-cycle discharge voltage of the gap. The unbalancing resistance is furnished by the resistors *c* and *d* which are enclosed in porcelain tubes mounted on the porcelain pillar *e*. These resistors have about 250,000

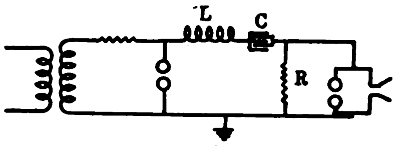

FIG. 4—IMPULSE GENERATOR CONNECTIONS

ohms resistance each and are of a special composition that retains its high resistivity under the most severe conditions of high voltage and high frequency. The resistors are about 30 cm. in length. The auxiliary electrode *f* is a pointed brass rod 0.08 in. (0.2 cm.) in diameter held in a ⅜-in. (0.95-cm.) diameter brass support member *g*, which is in turn mounted on an arm *h* of 1-in. angle iron. The hemispheres *j* mounted on horns are made of brass and are 12.5 cm. in diameter. In practise the charging resistance of the arrester is connected between the horn members *k* and *l*. For the purpose of test, *k* and *l* were connected and grounded to the frame of the gap structure.

The impulse discharge voltage of the gap was determined by a direct comparison with a 12.5-cm. sphere gap connected in parallel with it. The high-tension electrodes of the gap under test and of the sphere gap

were connected by a straight lead and the connection to the impulse generator was brought out from the middle point of this lead. The impulse generator itself was connected as shown in Fig. 4. The following cir-

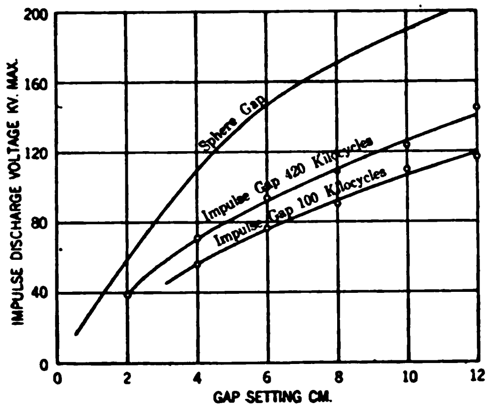

FIG. 5—IMPULSE DISCHARGE CHARACTERISTICS OF IMPULSE GAP COMPARED WITH SPHERE GAP

cuit constants were employed, giving very nearly critically damped impulse voltages.

For 100 kilocycle impulse:

$C = 5 \times 10^{-9}$ farad

$L = 1.25 \times 10^{-3}$ henry

$R = 1{,}000$ ohms.

For 420 kilocycles impulse:

$C = 5 \times 10^{-9}$ farad

$L = 8.3 \times 10^{-5}$ henry

$R = 320$ ohms

The condenser employed consisted of a stack of 100 impregnated paper condensers connected in series. Each condenser had a capacity of 0.5 microfarad. Single-layer inductances and water-tube resistors were

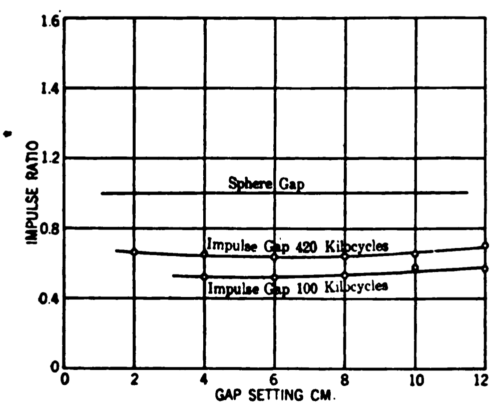

FIG. 6—IMPULSE RATIO OF IMPULSE GAP COMPARED WITH SPHERE GAP

used to complete the oscillating circuit. The test methods were identical with those outlined in the writer's previous paper.

Fig. 5 shows the impulse discharge voltage of the impulse gap plotted as a function of the gap setting. For purpose of comparison, a curve giving the impulse discharge voltage of a sphere gap is also shown. This curve also represents the 60-cycle discharge voltage of the impulse gap. The ratio between the impulse discharge voltage of a gap and its 60-cycle discharge voltage has been termed the "impulse ratio" by Mr. F.W. Peek.[2] The curves given in Fig. 6 show the impulse ratios of the impulse gap and of a simple sphere gap.

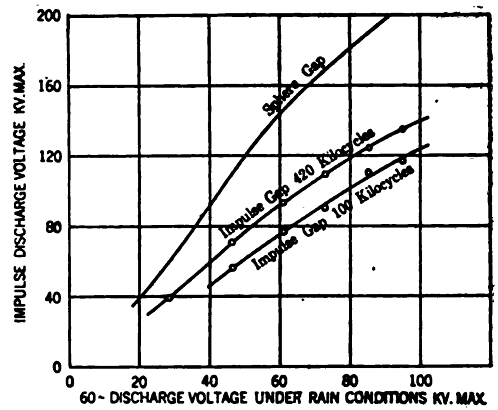

FIG. 7—IMPULSE DISCHARGE—THE 60-CYCLE DISCHARGE

When a lightning arrester spark gap is placed out of doors, the impulse ratio is not the proper criterion of the protective value of the gap. The spark gap must be so adjusted that it will withstand normal line voltage under the most unfavorable conditions. The gap setting necessary in service is, therefore, determined by the 60-cycle discharge voltage under rain conditions, since, in general, the 60-cycle discharge voltage of a gap is considerably reduced by moisture on the surface

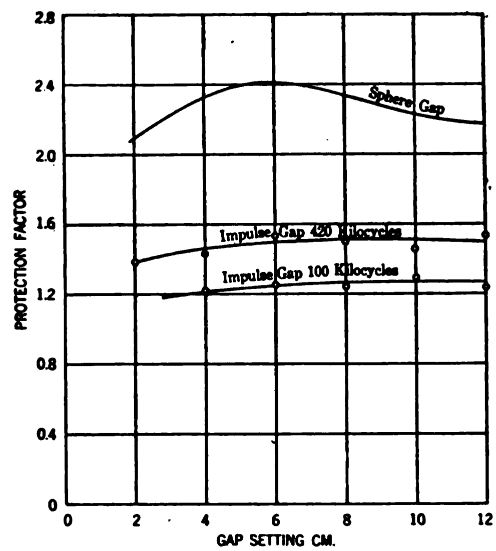

FIG. 8—PROTECTION FACTOR OF IMPULSE GAP COMPARED WITH SPHERE GAP

of the electrodes, such as is caused by rain or fog. The impulse discharge voltage, on the other hand, is practically unaffected by rainfall. The degree of protection against high-frequency disturbances afforded by the gap therefore depends on the ratio of the impulse discharge

2. F. W. Peek, Jr., "The Effect of Transient Voltages on Dielectrics." TRANS. A. I. E. E., Vol. XXXIV, 1915.

voltage of the gap to the 60-cycle discharge voltage *under rain conditions*. The term "protection factor" has been proposed for this ratio.[3] For a spark gap located indoors or otherwise completely protected from the weather, the protection factor will be the same as the impulse ratio.

Fig. 7 shows the impulse discharge voltage of the impulse gap plotted as a function of the 60-cycle discharge voltage under rain conditions, while Fig. 8 gives the protection factor as a function of gap setting. A comparison of Figs. 6 and 8 shows that the degree of protection afforded by a gap is considerably lessened where the gap is exposed to rain or dew. It is at once apparent that it would be highly desirable to provide some means for protecting a lightning arrester gap from the objectionable effects of adverse weather conditions without going to the great expense of constructing a shelter sufficiently large to cover the entire horn gap structure.

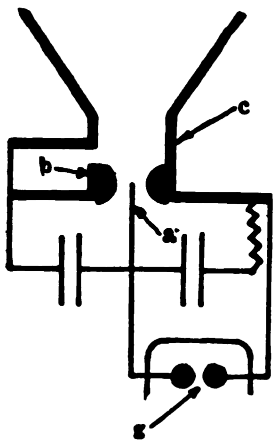

Fig. 9—Protected Impulse Gap

In a recent paper presented before the Institute[4], Mr. F. W. Peek described a very ingenious structure designed to obviate the difficulties due to rainfall without the necessity of providing a shelter over the arc-breaking horns of the gap. This "double balanced sphere gap," as Mr. Peek called his structure, consists of two sphere gaps in series. One of these gaps is sheltered from the weather and the design is such that the discharge voltage of the two gaps in series is determined largely by the discharge voltage of this sheltered gap. The arc-breaking horns are located outside the shelter. For a better description, reference is made to Mr. Peek's paper.

In his discussion of Mr. Peek's paper, the writer described a form of protected impulse gap that had previously been experimented with. This protected impulse gap is shown diagrammatically in Fig. 9. The gap structure shown in Fig. 3 was used for the main gap and a 6.25-cm. sphere gap g was connected between the auxiliary electrode and one of the main electrodes. The sphere gap g, shunting one-half of the main gap, may be sheltered from the weather

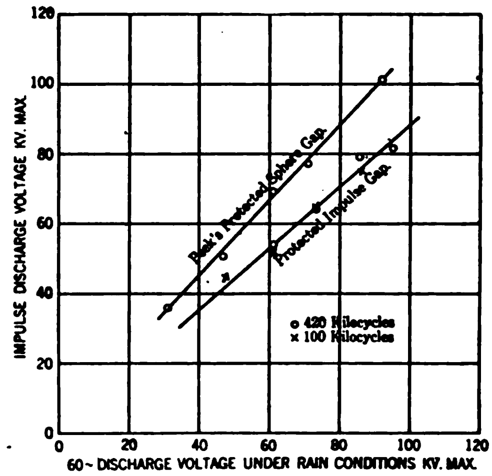

Fig. 10—Discharge Characteristics of Protected Gaps

while the main gap is exposed. The gap g is so set that it will discharge when the total voltage applied to the main gap equals the discharge voltage of the main gap under rain conditions. A discharge across g is followed immediately by a discharge between the auxiliary electrode a and the horn b. If g is so sheltered that its discharge voltage is independent of weather conditions, then the discharge voltage of the gap, as a whole, will also be substantially the same under all weather conditions. After a discharge has started across g and between a and b as described above, the rising arc quickly transfers from the auxiliary electrode a to the horn c, short-circuiting out the arc

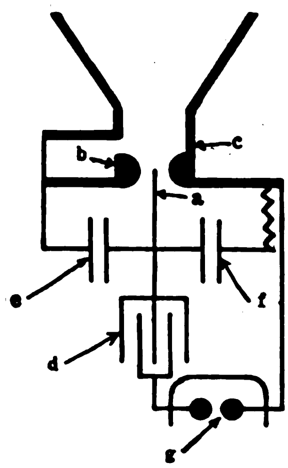

Fig. 11—Protected Impulse Gap

across g and effectively extinguishing it. This construction has been found to secure a very quick and effective suppression of the arc across g, thus permitting the use of a relatively small shelter.

3. C. T. Allcutt, Discussion of Mr. Peek's paper on "The Effect of Transient Voltages on Dielectrics—II." Proc. A. I. E. E., May 1919.

4. F. W. Peek, Jr., "The Effect of Transient Voltages on Dielectrics—II." Proc. A. I. E. E., May 1919.

Fig. 10 gives the impulse discharge voltage of Mr. Peek's double balanced sphere gap in comparison with the protected impulse gap described above. It is assumed in these curves that the shelter over the protected gap keeps the electrodes dry under all conditions. In the present state of development, however, there is some doubt as to the efficacy of these protected gap structures. It has been found that merely wetting the surfaces of the electrodes of a gap will reduce the discharge voltage to nearly as low a value as will actual rainfall. It is obvious that a shelter which merely protects a gap from direct rainfall does not necessarily prevent the formation of moisture on the electrodes in damp or foggy weather, and, unless the electrodes are kept dry under all conditions, the purpose of the shelter will be defeated.

Another form of protected impulse gap that has been experimented with by the writer is shown in Fig. 11. In this case, the gap g, shunting one-half the main gap, is in series with a condenser d that is of somewhat higher capacity than the condensers e and f. In this case, a discharge across g will throw a relatively large capacity in shunt with the gap between a and c so

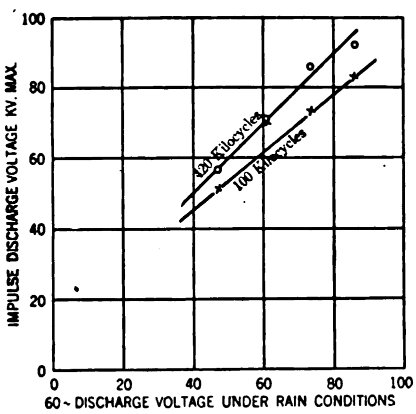

FIG. 12—PROTECTED IMPULSE GAP
See Fig. 11.

that most of the voltage will appear between a and b. A discharge between a and b is, of course, immediately followed by a discharge between a and c and a free discharge of the disturbances is permitted between the main electrodes b and c. In this case, no current flows across the gap g except the charging current of the condenser d. The discharge across g is only a fine "pin spark" so that it may be found possible to enclose g in a hermetically sealed chamber of small dimensions containing dry air. A gap of this character should be entirely independent of weather conditions. Fig. 12 gives the discharge characteristics of this form of protected gap. In obtaining the data for this curve, the main gap structure shown in Fig. 2 was employed. One-half the gap was shunted by a 6.25-cm. sphere gap in series with a capacity of about 10^{-10} farad. At present, it is impossible to say whether a protected gap of this type will be commercially practicable. The writer hopes to have more information concerning the possibilities of this device available for presentation at some future date.

It will be noted that the test data presented in this paper give only the results of tests up to 420 kilocycles. Tests have been made in the laboratory at far higher frequencies, but it is not believed that these higher frequencies represent conditions that actually occur in a transmission line. In a recent paper presented before the Institute, Dr. C. P. Steinmetz[5] showed that an infinitely steep wave-front traveling along a transmission line will be reduced to a frequency of 1000 kilocycles after traveling about 300 yards. The 420-kilocycle wave-front used in these tests represents an infinitely steep wave after having traveled about one mile. Some curves showing the discharge characteristics of the impulse gap with extremely steep wave-fronts (3000 kilocycles) applied were presented by the writer in his discussion of Mr. Peek's recent paper. These 3000-kilocycle tests, however, represented conditions that could not occur in practise, as an infinitely steep wave-front would be reduced to a frequency lower than this in less than 100 feet.

TABLE I

STANDARD 44-KV. IMPULSE GAP

Gap setting cm.	60 ~ Discharge		100-kilocycle impulse			420-kilocycle impulse		
	Dry kv. max.	Rain kv. max.	Kv. max.	Impulse ratio	Protection factor	Kv. max.	Impulse ratio	Protection factor
2	59.5	28.5				39.5	0.66	1.39
4	109	46.5	56.5	0.52	1.22	71	0.65	1.43
6	147	61	76.5	0.52	1.25	93.5	0.635	1.53
8	170	73	90.5	0.53	1.24	109	0.64	1.50
10	190	85.5	110	0.58	1.29	124	0.65	1.45
12	207	95	117	0.565	1.23	145	0.7	1.53

TABLE II

PROTECTED IMPULSE GAP SHOWN IN FIG. 9.

Gap setting cm.	Aux. gap setting cm.	60-cycle discharge rain	100-kilocycle impulse		420-kilocycle impulse	
			Kv. max	Protection factor	Kv. max.	Protection factor
4	0.87	46.5	45	0.97		
6	1.15	61	52	0.85	54	0.88
8	1.4	73	65	0.89	64	0.88
10	1.7	85.5	75.5	0.88	79	0.92
12	2.0	95			81.5	0.86

TABLE III

PROTECTED IMPULSE GAP SHOWN IN FIG. 11.

Gap setting cm.	Aux. gap setting cm.	60-cycle discharge rain	100-kilocycle impulse		420-kilocycle impulse	
			Kv. max	Protection factor	Kv. max.	Protection factor
4	0.87	46.5	51	1.09	56.5	1.21
6	1.15	61	68	1.12	71	1.16
8	1.4	73	73.5	1.01	86	1.18
10	1.7	85.5	83	0.97	92	1.08

5. C. P. Steimetz, "General Equations of the Electric Circuit." PROC. A. I. E. E., March, 1919.

Life and Performance Tests of O F Lightning Arresters

BY N. A. LOUGEE
of the General Electric Co.

I—LIFE RUN TESTS OF *O F* ARRESTERS

SINCE the first papers on the oxide film (*O F*) lightning arrester were given a little over two years ago,[1] the arrester has proved itself to be a worthy piece of apparatus by performance in regular

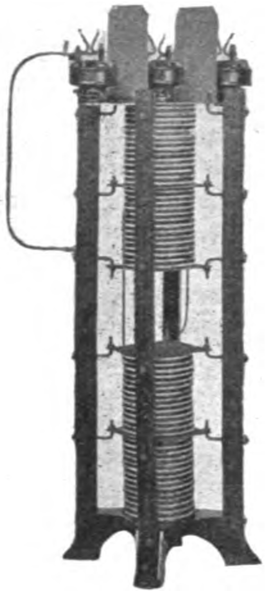

Fig. 1—Oxide Film Lightning Arrester for Indoor Service on Three-Phase Circuits, 5000-7500 Volts

service. Several hundred arresters up to 73-kv. rating, are now installed on both indoor and outdoor

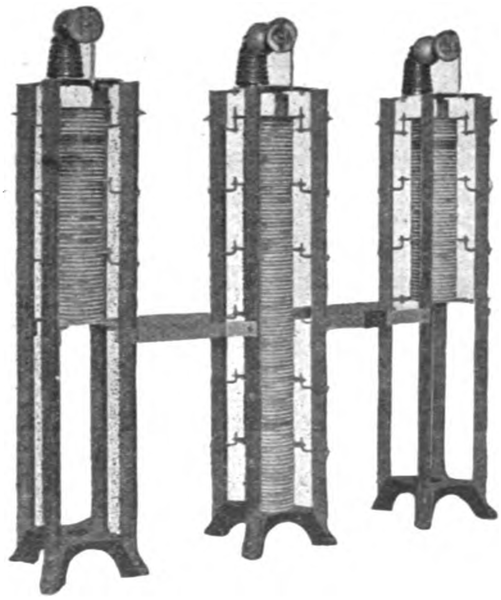

Fig. 2—Oxide Film Lightning Arrester for Indoor Service on Three-Phase Circuits, 15000-25,000 Volts

circuits, and higher voltage units will soon be in service. Figs. 1, 2, 3 and 4 show the typical designs used.

1. *The O F Lightning Arrester*, Trans., A. I. E. E., Vol. XXXVII, 1918.

To be presented at the Chicago Meeting of the A. I. E. E., November 12, 1920.

In Fig. 1, the three phase legs and the ground leg are all arranged in one stack, the bottom section being the ground leg. In Fig. 2, the three phase legs are the

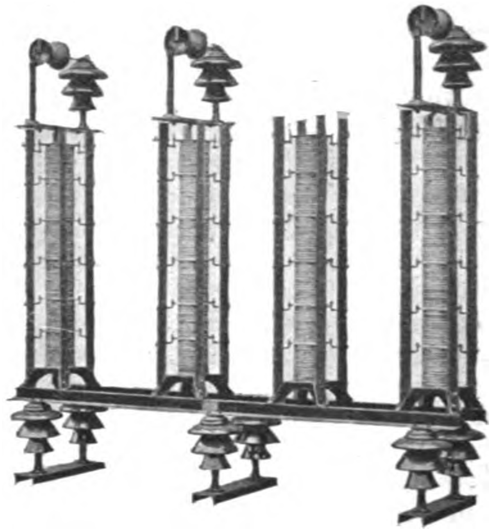

Fig. 3—Oxide Film Lightning Arrester for Indoor Service on Three-Phase Circuits, 37,000-50,000 Volts

upper sections and the ground leg is the lower section. In Figs. 3 and 4, the three phase legs and ground leg are set up parallel to one another. Fig. 5 shows the covered sphere gap used with the outdoor design, which permits of an indoor setting. Due to the small leakage current of these arresters (about 0.010 ampere),

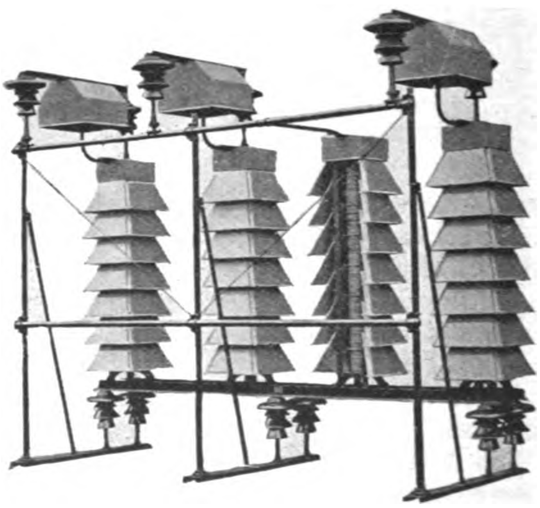

Fig. 4—Oxide Film Lightning Arrester for Outdoor Service on Three-Phase Circuits, 50,000-73,000 Volts.—Ground Stack Shields Removed for Cell Inspection and Test

it is not necessary to use horn gaps to aid in breaking the arc, and it is, therefore, possible to use the covered sphere gap which has previously been described in the proceedings of the Institute.[2] Fig. 6 shows the

2. *The Effect of Transient Voltages on Dielectrics—II*, F. W. Peek, Jr., Trans., A. I. E. E., Vol. XXXVIII.

testing device used and its method of operation, about which more will be said a little later.

The life of a lightning arrester is a very important factor, and one that has to be estimated from both operating and laboratory data. Operating data obtained during the past five years show that little deterioration has occurred to the *O F* cells. Cells have been returned from typical installations and tested and little, if any, change has been found.

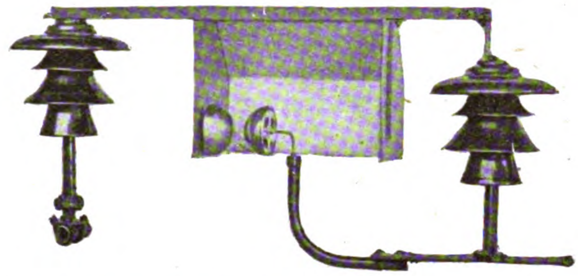

Fig. 5—Covered Hemisphere Gap as Used on Outdoor Type Oxide Film Arrester—50,000-73,000 Volts—Section of Cover Omitted to Show Gap

Fig. 7 is a view of an opened returned cell, and shows the film side of the electrodes and the porcelain spacer. The lead peroxide (PbO_2) filler has been removed. This cell was returned recently from a 13,000-volt arrester installed early in 1916, and which has been subjected to much more than average service, due to its location and surroundings. The few white spots in the illustration are discharge areas covered with yellow litharge (PbO). This PbO area or plug is what has caused the cell to reseal after the surge has passed through, and is reduced from the PbO_2 filler by the heat of the current through the small discharge spot in the film. The larger dark areas are where some

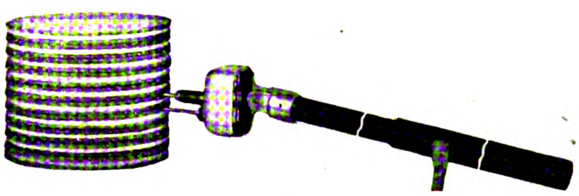

Fig. 6—Oxide Film Cell Testing Device in Position for Testing

of the PbO_2 filler is still adhering to other discharge areas, and the light background is the varnish film. The lead peroxide filler showed no change.

To obtain information on the life of *O F* arresters several years ahead of outside reports, however, an intensive test has been running during the past few years. Fig. 8 gives the general scheme of circuit used.

In Fig. 8, the surge circuit is shown to the right and consists of the usual inductance, capacitance and air gap, used to obtain oscillations. The 50,000-volt transformer charges the condensers, which, upon breaking down the air gap set for a little under 50,000 volts, cause the surge through the arresters. The transformer to the left supplies the dynamic 60-cycle voltage to all the arresters running on this particular voltage. Ordinarily all the lever switches are down (Fig. 8 shows only one particular voltage, one arrester and one set of switches. With this arrangement the arresters are separate from the

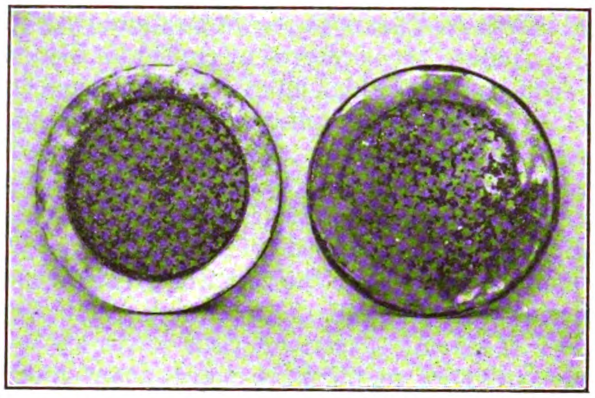

Fig. 7—Inside of Electrodes of *O F* Lightning Arrester Cell Returned From 13,000-Volt Installation After Four Years of Service

surge circuit. When it is desired to surge any one particular arrester, the upper lever switch corresponding to this arrester is thrown, thus paralleling the two transformers supplying dynamic voltage. The lower lever switch is then opened and this particular arrester is still on dynamic voltage, but also on the surge circuit which can now be thrown on. After surging, this arrester is thrown back on the regular dynamic transformer, and the next arrester put through a similar operation. This

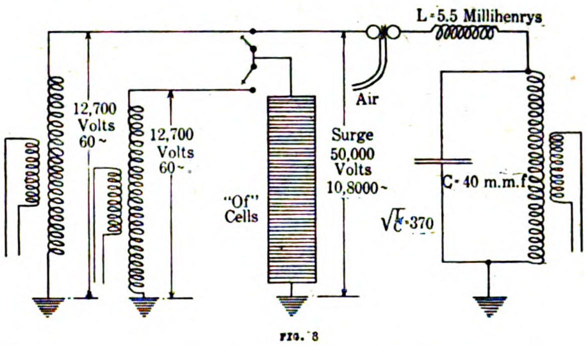

Fig. 8—Circuit Connection Used in Intensive Life Run Tests

arrangement of transformers and switches permits the regular dynamic voltage to all the arrester to be uninterrupted during surging operations.

O F arresters were placed on 330, 2300 and 12,700 volts respectively at 60 cycles with no series gap, and all arranged as shown in Fig. 8. These arresters have been surged daily, the surge current through the arresters having a maximum peak value of about 50 amperes and dying down to about 20 amperes at the end. This surge, having a surge impedance of 370 ohms is representative of an actual surge on a line, except that

the average actual surge has a higher frequency and may at times be more powerful. It has been found, however, that the lower the frequency of a surgé, the more difficult it is for an arrester to seal.

330-Volt Circuit—Single O F Cells.

These cells take from 5 to 75 milliamperes leakage current and run at a temperature of about 50 deg. cent. It took about four years to record a failure with these cells. A failure then occurred by enough of the PbO_2 being reduced to cause high internal resistance and hence loss of protection. The voltage across the cells being, of course, always the same, causes this group of cells to be more permanent than the 2300- and 12,700-volt arresters. With these latter arresters the voltage distribution across the various cells may change. This adds one more variable to the action of arresters consisting of more than one cell.

2300-Volt Circuit—Eight O F Cells in Series.

These arresters so far have acted about like the single cells; that is, voltage distribution has remained normal. Voltage distribution is obtained by means of shunting vacuum tubes, which break down or glow at various voltages, across each cell in turn. It is the same idea used to test the cells in service as shown in Fig. 6. For service conditions a vacuum tube which will glow at about 1000 volts a-c. is used. As the internal condition of a cell changes, and more particularly the film, the voltage drop when in series with a number of cells may change. Although this is not an infallible method of picking out poor cells in service, it does give a reliable indication in most cases. For voltage distribution tests, tubes breaking down between 100 and 2300 volts a-c. respectively are used. For convenience in interpolating these data, a cell having a voltage drop of less than 200 is designated low, from 200 to 400 is designated normal, from 400 to 600 is designated high, and above 600 is designated very high. The results can then be plotted against the respective cells by using a different color for each of the above four groups. The units on 2300 volts have shown with one or two exceptions only normal cells on voltage distribution, and the few low or high cells which have appeared from time to time, have returned again to normal. The leakage current of this group of arresters varies between 1 and 10 milliamperes, and the cells run at a temperature of about 40 deg. cent. A few units have failed or lost their protection after four years of continuous service.

12,700-Volt Circuit—Forty-seven O F Cells in Series.

These arresters have been running almost two years with no appreciable deterioration. To obtain the relative effect of dynamic and surge, similar arresters were run with different service characteristics, as follows: (a) dynamic only, (b) dynamic and surge, (c) surge only and (d) idle. The leakage current is from 5 to 10 milliamperes and about the same through all the arresters. The temperature is about 35 deg. cent. at the top of the stack, 45 deg. cent. in the middle and 30 deg. cent. at the bottom of the stack. Results to date show that (a) and (b) types of arresters give about the same characteristics; that is, the daily surge has no ill effect on the arresters. Both (a) and (b) show a gradual tendency for low-voltage cells to appear at the bottom of the stack and higher voltage cells at the top. Here again no change has been found to be absolute; that is, unless a cell is extremely high, it may go from low to high and back again. The low cells at the bottom of a stack may be due to either capacity or temperature, but probably the latter, as all the cells are about normal when first put on the circuit. The (c) and (d) types of cells show a general scattering of high and low cells throughout the stack.

This sort of intensive test has been found extremely valuable in trying to determine ahead of time what might occur in service and also for determining the effect of changes. So far as applying to standard arresters in service, it seems fair to assume that if an arrester will stand, say four years, under such an intensive test, it will stand up several times four years in actual service. Of course, it is always possible that a more or less direct lightning stroke or a long arcing ground will destroy an arrester, so this conclusion should apply to normal average service. As yet the factor to use between test and actual service is not known, but should be when longer service results are available.

II — PERFORMANCE OF *O F* ARRESTERS

The efficiency of a lightning arrester is governed by four factors; namely, sensitiveness, current discharge capacity, reseal and life.

Sensitiveness. As most electrical apparatus is tested at twice normal voltage, an arrester should be able to begin discharging at about this voltage. This means a horn or sphere gap should not be set for over double voltage for best results.

To care for steep wave impulses the time lag of the arrester should be a minimum.

Current Discharge Capacity. To discharge the energy from a surge, the discharge path must be of a sufficiently low resistance to prevent the voltage drop being above the insulation strength of the apparatus connected to the line. Again since a double voltage test is given apparatus, the discharge capacity of an arrester is usually given at double rated voltage.

Reseal. Reseal is the act of cutting off the discharge path through the arrester when the voltage across the arrester has returned to normal. The quicker this can be accomplished the better it will be, for if an arrester has sufficient discharge capacity, dynamic or line frequency current following, not only will be apt to destroy the arrester but may also cause bad disturbances on the line.

Reseal should also permit an arrester to be ready immediately for another discharge, for with a lightning storm over a large area of transmission lines, it is fair to assume that impulses and surges can occur extremely

close together; that is, at least a second apart, and sometimes several per second.

Life. It is difficult to define exactly what the life of a satisfactory arrester should be, but a good arrester should easily withstand the average surge or impulse. Arcing grounds are the most dangerous type of discharges and as they vary greatly in severity, depending upon the system and just where they occur, it is difficult to state how long an arrester should care for one.

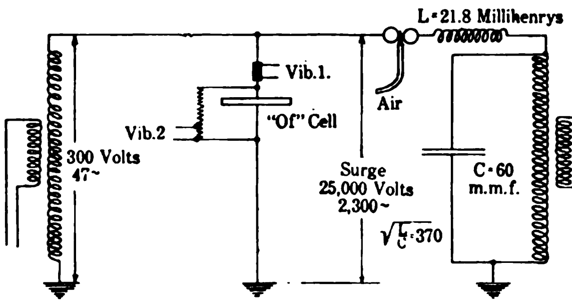

Fig. 9—Circuit Connection Used for Surge Tests

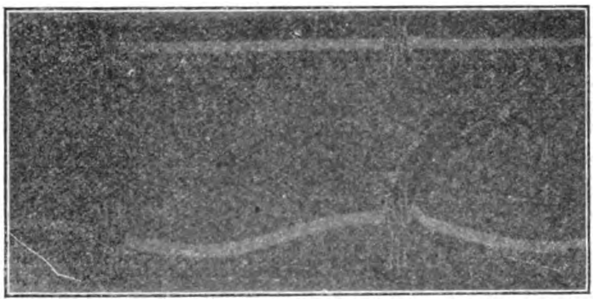

Fig. 10—*O F* Cell on Circuit in Fig. 9
Vibrator 1—Current through arrester, 1 mm. = 5 amperes (peak value)
Vibrator 2—Voltage across arrester, 1 mm. = 85 volts (peak value)

Tests. The following results are given to show how the *O F* arrester acts in regard to the above points. A single cell was used in all the following tests in order to obtain as powerful discharges through the cell as possible with the power available.

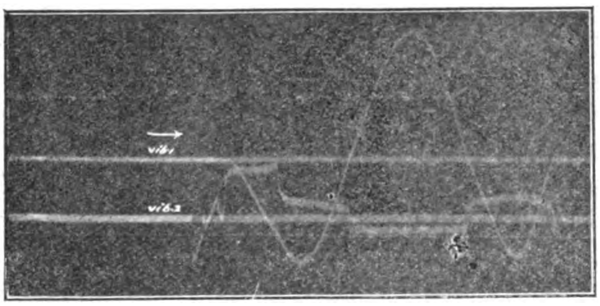

Fig. 11—*O F* Cell on a 600-Volt, 40-Cycle Circuit
Vibrator 1—Current through arrester, 1 mm. = 100 amperes.
Vibrator 2—Voltage across arrester, 1 mm. = 22 volts.

The first set of tests was made with a circuit as shown in Fig. 9. The usual surge circuit is used, which superimposes the 25,000-volt, 2300-cycle surge on the dynamic 300-volt, 47-cycle circuit. Fig. 10 shows an oscillogram of the discharge of an *O F* cell on this circuit. Vibrator 2 shows the dynamic 47-cycle voltage across the arrester with the 25,000-volt, 2300-cycle surge superimposed. The voltage peaks are kept at about double voltage and the cell reseals without permitting any dynamic current to follow; that is, this test shows that *reseal* and *sensitiveness* are satisfactory.

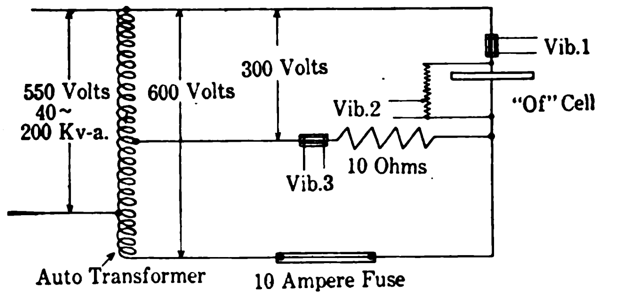

Fig. 12—Circuit Connection Used for Double-Voltage Surge Tests

Although the discharge through the cell is about 50 amperes, since the surge is supplied by a 15-kv-a. transformer, this test is not enough in itself to demonstrate that the discharge capacity is satisfactory.

Fig. 11 shows an oscillogram taken with 600 volts, 40 cycles (double standard voltage) impressed across an *O F* cell, to show current discharge capacity. The current peaks are 3500, 4200 and 3300 amperes respectively, and the voltage peaks 110, 89 and 154 volts respectively, giving an internal resistance of 0.031, 0.021 and 0.047 ohm respectively. Due to the low resistance of the *O F* cell and its relative value to the impedance of the circuit, the impressed voltage of 600 was not sustained across the cell when the high current flowed. This *current discharge capacity* is extremely high and should be ample under all conditions. The internal resistance of a cell will vary between 0.01 and 0.1 ohm, depending upon the particular path through the cell the discharge happens to pick out.

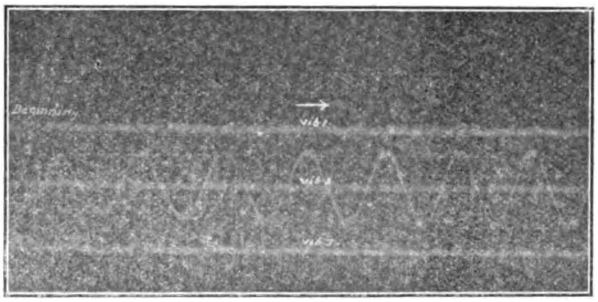

Fig. 13—*O F* Cell on Circuit in Fig. 12
Vibrator 1—Current through arrester at 600 volts, 1 mm. = 100 amperes
Vibrator 2—Voltage across arrester, 1 mm. = 22 volts.
Vibrator 3—Current through arrester at 300 volts, 1 mm. = 5 amperes.

Fig. 12 gives the connection used for a double voltage surge test with normal voltage immediately following. This is accomplished as shown by bringing out a tap from the transformer at 300 volts (standard volt-

age) and connecting it through a low resistance to the arrester cell. The resistance is necessary to prevent the lower section of the transformer from becoming short-circuited. With this connection, 600 volts are supplied to the arrester until the fuse opens, and the lower half of the transformer then being cut off, 300 volts are continued across the arrester cell. This is about the most severe test that can be given a lightning arrester and only an arrester which has a *low breakdown, good current discharge capacity* and *good sealing characteristics*, will act satisfactorily. Referring to the oscillogram taken on this circuit shown in Fig. 13, the switch impressing 600 volts across the cell closed at the extreme right. The cell immediately broke down and discharged 2700 amperes. This current after one-half cycle blew the 10-ampere fuse, thereby cutting off one-half of the transformer, and causing the voltage across the cell to drop to 300 or normal. There was then a sealing current of about 2 amperes for several cycles shown by vibrator 3, which caused the small breaks in the voltage wave. After a few seconds the current through the cell had dropped to normal or a few milliamperes.

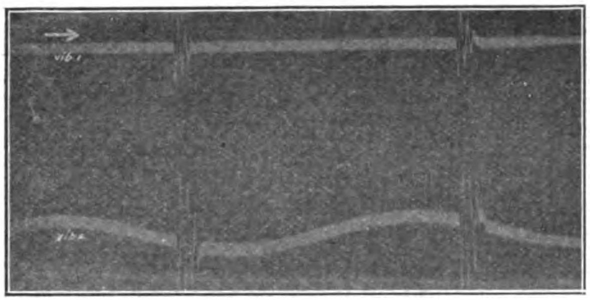

FIG. 14—*X* ARRESTER ON CIRCUIT IN FIG. 9

Vibrator 1—Current through arrester, 1 mm. = 5 amperes (peak value)
Vibrator 2—Voltage across arrester, 1 mm. = 85 volts (peak value).

To show the relation of protection and current discharge capacity, oscillograms were taken of single *O F* cells with external resistance in series on the ciruit shown in Fig. 9. *X* represents an arrester with a medium internal resistance and having a discharge capacity at double voltage of 60 amperes. *Y* represents an arrester with a higher internal resistance and having a discharge capacity of 20 amperes at double voltage.

Fig. 14 shows an oscillogram taken with arrester *X* and Fig. 15 an oscillogram taken with arrester *Y* on this circuit. It will be noted that the voltage peaks with *X* are 1600 and with *Y* 3650, as against 900 with the standard cell, which was shown in Fig. 10. Moreover if the frequency were nearer what is obtained in actual service, that is, from 10,000 to 100,000 cycles instead of 2300 cycles which had to be used for oscillographic work, this difference would have been much greater due to the higher impedance of the transformer at the higher frequencies. To give, therefore, satisfactory protection, an arrester must have a good current discharge capacity on double voltage and more than these *X* and *Y* arresters show. *X* and *Y* also show the bad effect of a poor ground connection.

The *life* of an *O F* arrester was discussed in Part I, Life Run Tests on *O F* Arresters, and is believed to be satisfactory.

Sensitiveness in service is limited by the gap setting, but since no dynamic current follows a surge discharge and the leakage current is only a few milliamperes, this gap setting can be small. The gap settings used in service correspond to line voltage, so the breakdown between phases is double voltage and the breakdown to ground is 1.7 times the voltage to ground. Since the covered gap is used for outdoor installations a dry or indoor setting can be used.

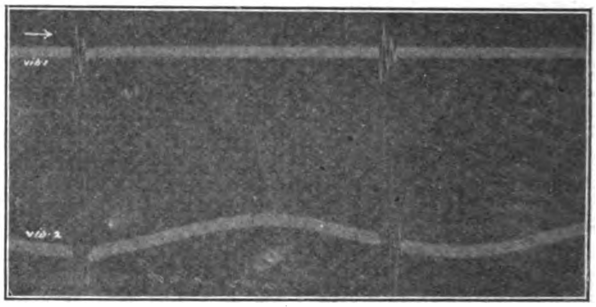

FIG. 15—*Y* ARRESTER ON CIRCUIT IN FIG. 9

Vibrator 1—Current through arrester, 1 mm. = 5 amperes (peak value).
Vibrator 2—Voltage across arrester, 1 mm. = 85 volts (peak value).

The author wishes to express his appreciation to Mr. E. E. Burger for his valuable assistance in obtaining the data used in this paper.

INVESTIGATIONS IN THE AUTOMOTIVE FIELD

Sometime ago, the Bureau of Standards commenced an investigation of the value of various systems of pre-heating the air-fuel mixtures used in automobile engines. A paper on this subject was presented at the June meeting of the Society of Automotive Engineers. Work has been continued and more complete data secured concerning the effect of different degrees of heating on engine economy, acceleration, etc. Several special fuels to be used in the airplane engine tests carried out in cooperation with McCook Field, have been analyzed as well as some blended fuels submitted for investigation by the Inventions Section of the War Department. Apparatus has been set up and test commenced to determine the performance of fan belts for the Motor Transport Corps. The apparatus consists of a motor driving a typical automobile cooling fan by means of a belt; the slippage can be determined by means of revolution counters attached to the motor and the fan pulley.

Surface Creepage and High-Voltage Insulation

BY T. NISHI

Tokyo Imperial University

1. Introduction

THE fundamental principle of designing high-voltage insulation, such as bushings, insulators etc., is obviously the application of electrostatics. A close examination of the evolution of the present methods of designing, however, will reveal the fact that it has been based very much upon experience rather than rational design. If the design were executed in rigorous accordance with the theory of electrostatics, the result would not necessarily be satisfactory, but very often lead to failure.

The main difficulty of high-voltage insulation design, as is well-known, is how to deal with the surface creepage, *e. g.*, discharge through the surface film of the dielectric; because the design of most insulators consists in the design of an air insulator rather than of an insulator of dielectrics, and the apparent dielectric strength of air just outside the dielectric is considerably lower than that in free space. Hence, in most cases of designing high-voltage insulation, the designers used to be confronted with this erratic phenomenon; the surface creepage, which stands outside the domain of any known electrical theories.

Sufficient information concerning the surface resistivity of a number of insulating materials is now available,[1] but the usefulness of such knowledge for the design of high-voltage insulation is rather limited, because the measurements of surface resistivity were made by low-voltage direct current and therefore the conditions of the measurement are far from the actual working conditions of high-voltage insulators, etc., where the surface is subject to intense field and very often surrounded by ionized air. As a natural consequence, the design had to be based upon practical experience, and sometimes would result in considerable unnecessary expenditure of money and labor.

From some experiments made in the Electrical Engineering Laboratory in Tokyo Imperial University and in the High-Voltage Laboratory of Leland Stanford Junior University, the author has found that the main cause of erratic surface creepage is the accumulation of free charge on the surface of (very probably also inside) the dielectric of which the bushings insulators etc. are made. The results of the experiments will be given below, though they are rather qualitative than quantitative owing to the extreme difficulty of exact measurement. The author hopes that these experiments may induce farther investigation on this subject with the result that the high-voltage insulation will be designed on a more scientific basis than at present.

1. *Bulletin, Bureau of Standards.* No. 234. June, 1914.

2. Accumulation of Free Charge on Dielectrics in Electric Field of High Intensity

(*I*) *Method of Measurement.*

The accumulated charge on the dielectric was measured by a ballistic galvanometer or a quadrant electrometer as shown in Fig. 1. The specimens were, in most cases, of the form of a slab. To measure the charge on the surface of a specimen, the slab was placed on a grounded metallic plate with the charged surface up. The metallic plane A (proof plane) which was earthed through the

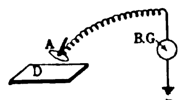

Fig. 1A

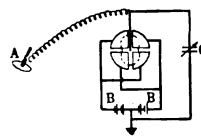

Fig. 1B

ballistic galvanometer BG, was suddenly placed on the spot of the dielectric where the charge was to be measured and at the same time the ballistic throw caused thereby was read. When the charge was too small and the sensitiveness of the galvanometer was insufficient for its measurement, the quadrant electrometer was used as shown in Fig. 1B, where B was the polarizing battery and C was an adjustable air condenser, through which the sensitiveness of the system could be changed at will.

(*II*) *Behavior of Dielectrics in Alternating Field.*

(*a*) *Under Spherical Electrode.* The specimen was placed between a spherical conductor 2.5 cm. in diameter (upper electrode) and a grounded metallic plate (lower electrode). In the first case, the specimen was in direct contact with the grounded plate, and the distance of the spherical elctrode from the upper surface of the dielectric was 10 cm. In the second case, the specimen was held just midway between the two electrodes. The distance of the electrodes from the opposing surfaces of the dielectric were 5 cm. each.

The alternating voltage was applied between the electrodes by a transformer, the primary voltage of which was regulated by means of an induction regulator. After applying the alternating e. m. f. for one minute, the field was taken away by opening the primary switch of the transformer or sometimes the voltage was gradually lowered to zero by turning the handle of the induction regulator. Immediately after taking away the field, the accumulated charge on the dielectric was measured by the method described in the preceding paragraph.

The dielectrics tested were paraffin wax, beeswax, ebonite, bakelite, glass, mica (crystaline), varnished cambric, oiled cloth, and mineral oil. They behaved,

however, in a similar manner, and, therefore, the typical results only are shown in Figs. 2, 3, 4 and 5.

The abscissas of these curves represent the effective values of the voltages applied between the electrodes, and the ordinates the ballistic throws of the galvanometer, or the deflections of the electrometer, that is to say, the accumulated charge in arbitrary units.

It will be noticed that, in every case, a negative

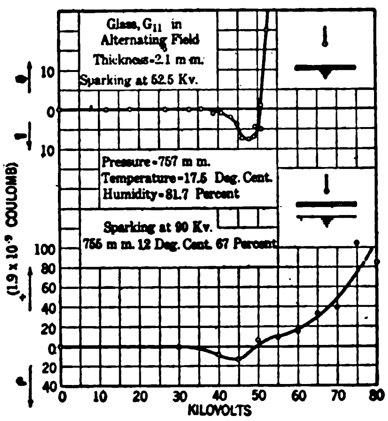

FIG. 2

charge appeared first at a certain intensity of the field and when the voltage was raised further, the charge changed its sign, *i. e.*, there appeared a positive charge, and finally a sparking discharge took place.

It is to be emphasized that, in the above experiments, the appearance of the free charge was found always to be accompanied by a corona discharge at the surface of the spherical electrode. The conclusion was drawn therefore, that the chief cause of producing

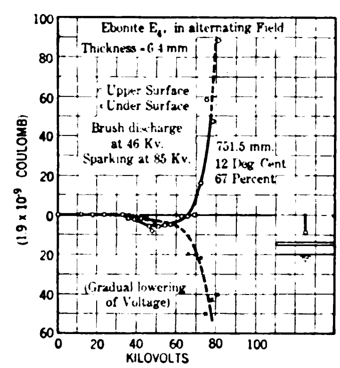

FIG. 3

the free charge is the action of the ions in air, and this fact is supported by other results which will be described in the following paragraphs.

The thickness of the dielectrics and the distance of the upper electrode seemed to have considerable effect on this phenomenon, but it was impossible for the author to touch upon this point owing to lack of time.

(*b*) *Under Needle Electrode*. The procedure in these experiments was the same in those referred to above, and the typical results are shown in Figs. 6, 7, 8, 9 and 10.

In this case, the charge appeared at far lower voltage than in the former case. Very probably such effect was mainly due to the fact that the corona started at lower voltage and not to the different distribution of electric field at the surface of the dielectrics.

The change of the sign of the accumulated charge does not take place at the same voltage throughout the whole surface of the dielectric, but the charge at

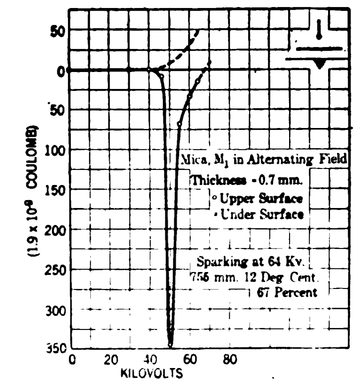

FIG. 4

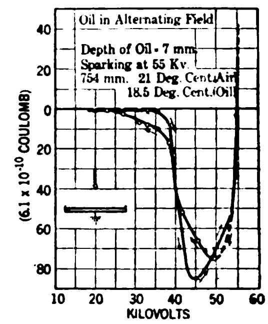

FIG. 5

the central part, *i. e.* just under the electrode changes its sign at a lower voltage than in the surrounding region. This fact was clearly demonstrated by the experiment where in a metallic plate of ring form was used in addition to the disk as proof plane. The specimen was subjected to an intense field for one minute, such field was then removed and immediately thereafter the disk was placed on the surface just under the needle point and the ring was placed con-

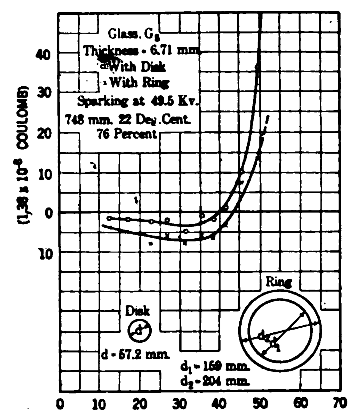

FIG. 6

centrically therewith. The results obtained by this procedure are shown in Fig. 6, 7 and 8. The question whether such effect is due to the special distribution of positive and negative ions in the discharge from the electrode, or due to merely the difference in intensity of the field on the surface of the dielectric, can not be answered at present owing to lack of experimental results.

When the voltage was gradually lowered, the

accumulation of free charge was far less than when it was taken away by opening the primary switch of the transformer, as shown in Fig. 7, 8, 9 and 10. This cannot be accounted for merely by the leakage in ordinary sense, because this tendency is most remarkable in paraffin wax, which has much higher volume and surface resistivity than other dielectrics.

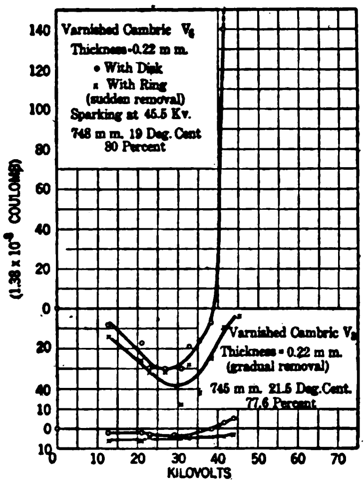

Fig. 7

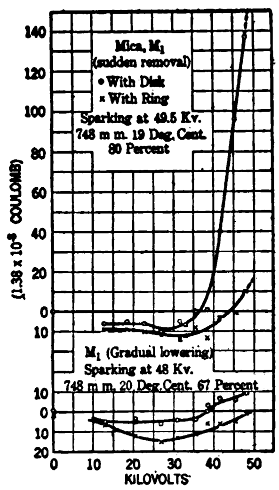

Fig. 8

At present, however, sufficient evidence has not been obtained to suggest an explanation for the above results though the author is inclined to believe that the accumulated charge is neutralized by the ions in air while the voltage is gradually lowered.

(c) *Between Disk and Plate Electrodes.* The specimen was placed between a brass disk 15 cm. in diameter and a grounded metallic plate so as to test the dielectric strength of the specimen. In this case, the charge accumulated on the surface around the disk was measured by means of ring-formed proof plane immediately after the electric field had been gradually taken away and the disk had been removed.

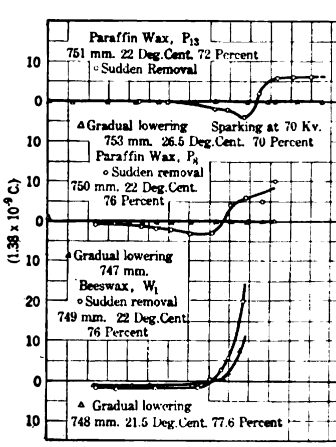

Fig. 9

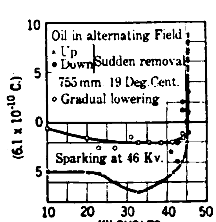

Fig. 10

The results are materially of the same nature as in the above cases and are shown in Fig. 11.

Certainly the observed values of the accumulated charge differ to a great extent from those while the field is on, because, in such an arrangement of the electrodes as used here, the leakage of the accumulated charge would be far greater than in the case where the upper electrode is not in contact with the surface of the specimen. It follows that these results are of comparatively minute value for differentiating the properties of one dielectric from the others. Nevertheless it is worth remarking that the observed values

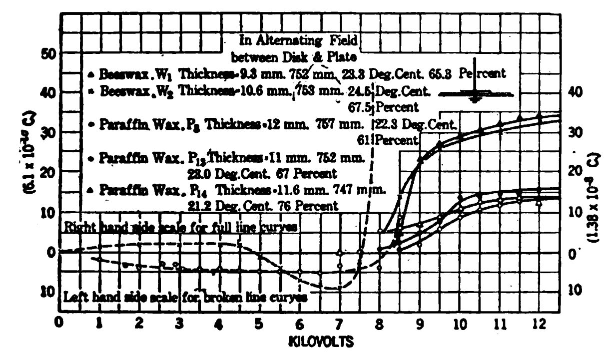

Fig. 11

of the accumulated charges for different specimens of the same material fall in near each other as shown in Fig. 11. And furthermore the result is instructive for illustrating the process of creeping discharge through the surface of the dielectric, which will take place if the applied voltage is high enough and the dielectric slab is not very wide.

Throughout the above experiments in three cases, it appeared that high dielectric constant was one of the favorable conditions for the accumulation of free charge on the surface of dielectrics, though the author is inclined to believe that the property of the materials relating to this phenomenon is of different nature from that we call dielectric constant, but may be something related to the photoelectric property of the materials.

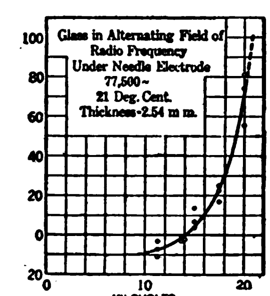

Fig. 12

(d) *Under Needle Electrode in Alternating Field of Radio Frequency.* This part of the research was carried out in the high-voltage laboratory at Stanford University by Professor Harris J. Ryan and the author.

The arrangement of the electrodes and the procedure of the experiment were the same as in (II) (b) except that the time of electrification was shorter, viz. 30 seconds. The result is shown in Fig. 12. The radio frequency field of high intensity was produced by a Poulsen arc-generator. We could not obtain the curve for wide range of the voltage owing to the unsteadiness of the arc, but the general characteristic can be conceived from the curve. It is very interesting or rather surprising to find that the dielectric behaves

in almost the same way in radio frequency field as in 50-cycle field. Also it may readily be noted that the positive charge appeared at a far lower voltage than when the dielectric was placed in 50-cycle field.

The author can hardly give a satisfactory explanation for the observed difference. Very probably it is mainly due to the difference in the amount and the behavior of ions in the two alternating fields of different frequency.

Anyhow the result is extremely valuable as the clew

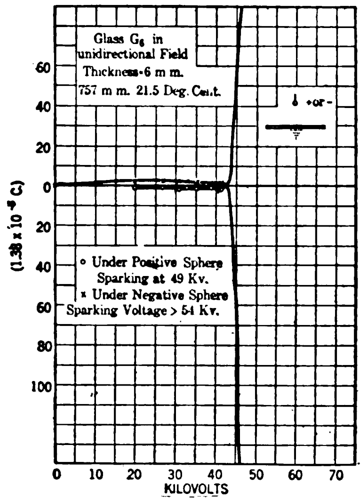

Fig. 13

for disclosing the secret in the dielectric phenomena and further study in this line is most desirable.

After this experiment had been made, the author found that some experiments on the behavior of dielectrics under the action of radio frequency point discharge had been carried out about twenty years ago by Knoblauch.[2] He used a Tesla coil and showed the accumulated charge on the surface of dielectrics by means of Lichtenberg's dust-figure.

According to his view, the above results may be accounted for as follows: The discharge from a pont electrode is of cone form, near the axis of which there are copious positive ions, while the negative ions are surrounding the former in the form of mantle. While the voltage is low, the negative ions predominate over the positive, and as the voltage is raised, the positive ions increase in number and can reach further and further. As a result, the accumulated charge changes its sign at a certain voltage and the area of positive region spreads over the surface as the voltage is raised further.

Though his theory is based upon several experimental facts and very excellent for the explanation in simple cases, the phenomena are too complicated and cannot be explained by such a simple theory in some cases which will be described later.

(III) Behavior of Dielectrics in Unidirectional Field.

(a) Under Spherical Electrode. The arrangement of the electrodes and the procedure of the experiment were the same as in the case of alternating field. To produce unidirectional field of high intensity, we used the combination of a transformer and a kenotron or in some cases a mechanical rectifier. The applied voltage between the electrodes was smoothed out by means of condensers, inductances and high resistance, and the field was not absolutely steady, but somewhat pulsating.

The typical results are shown in Fig. 13 and 14. It is noticeable that the charge appearing on the upper surface is of opposite sign to that of the upper electrode while the voltage is comparatively low, whereas the charge changes its sign abruptly at a certain value of the applied voltage, and if the voltage is further raised, the accumulation of the charge would rapidly increase as shown in these curves.

In the author's opinion, the charge which appears at comparatively weak field is of the same nature as ordinary residual charge as is observed in absorbing condensers, while at high intensity of the field, the charge is caused to appear by the ions in air. The ions in air, if produced, would accumulate themselves on the surface of the medium of higher dielectric constant. Furthermore the author suggests, though not supported by any definite experimental evidence, that there would be going on the process similar to the ionization of gas, that is to say, the charge may be produced by the bombardment of the ions under high electric force. Though not very definitely observed, the change of sign of the accumulated charge appeared

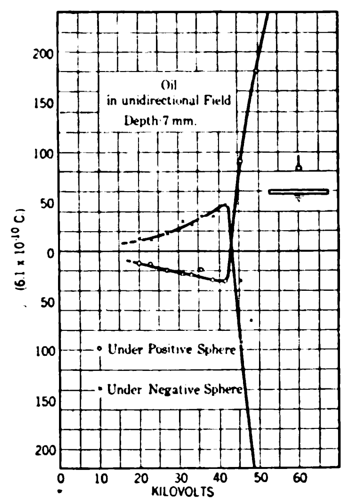

Fig. 14

to take place when the corona started on the surface of the sphere.

(b) In Uniform Field Practically Free from Ions. To ascertain the fact that the electrification of the dielectric when unaffected by the ions in air has the opposite sign to that of the electrode facing its surface, the specimens were tested, being placed midway between two large disk electrodes, the edges of which were rounded off with large radius as shown in Fig. 15. In such an arrangement of electrodes, it would be

2. *Ann. d. Phys.* 6 p. 353. 1901.

safely assumed that the ions in air are very few even when the potential difference between the electrodes is of comparatively high value. The author regrets that he could not apply the high-voltage source so as to make the middle point between the electrodes at zero potential, but was obliged to ground one of the electrodes because of the construction of the mechanical rectifier used.

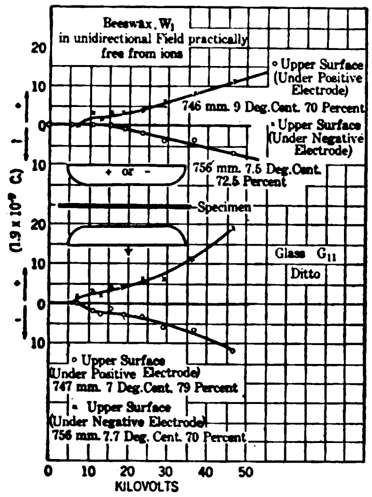

Fig. 15

The typical results are shown in Fig. 15. As had been expected, the accumulated charge on the top surface is of the opposite sign to that of the upper electrode.

The above results are very significant, because the phenomenon is in intimate connection with dielectric

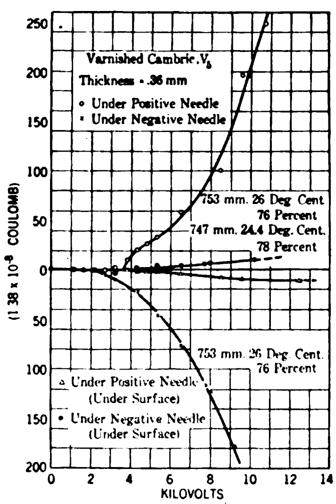

Fig. 16

absorption which is a long-disputed problem among physicists and electrical engineers.

We can account for the charge appearing in this case in two different ways. One of them is to suppose that the polarization of the dielectric remains after the field is off, and the other is to suppose that the ions in the dielectric were moved under electric force so as to accumulate near the surfaces and they could not recombine owing to their very low mobility in the solid dielectric after the field had been taken away. Which of them is correct is the most important determination of all dielectric problems and at present any definite answer cannot be given to the question owing to the scarcity of experimental data, though the author is inclined to believe the latter theory.

(c) *Under Needle Electrode.* The procedure of the experiment was the same as in the case of alternating

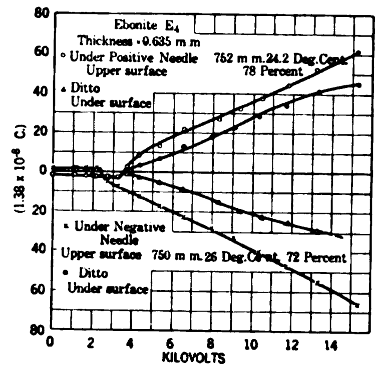

Fig. 17

field, and the typical results are shown in Fig. 16, 17 and 18.

In this case, the charge on the upper surface has always the same sign as the needle electrode. Very probably the charge observed in the above experiment (III) (b) is entirely masked by the charge due to the ions in air because of the copious ion supply at the needle point.

It is also noticeable that the charge appears at a lower voltage when the needle is negative than when

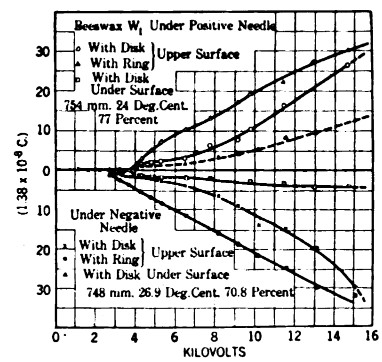

Fig. 18

it is positive. This may be accounted for by the fact that the voltage required to start corona is lower when the needle is negative than when it is positive. And this is one of the evidences to support the theory that the charge on the surface of the dielectric is produced by the action of the ions in air.

This theory is also supported by the results shown in Fig. 18, where the charge was measured with two different proof planes, disk and ring-formed, as in the

case of alternating field with needle electrode. Notwithstanding the difference in electric intensity where they are placed, the charges appeared at the same voltage as shown in Fig. 18. This shows that the presence of ions is one of the necessary conditions for the accumulation of free charge on the dielectric in intense field. It is also conceivable that the normal component of electric intensity is essential to the production of free charge on the dielectric, if the ions in air are the principal cause of the effect.

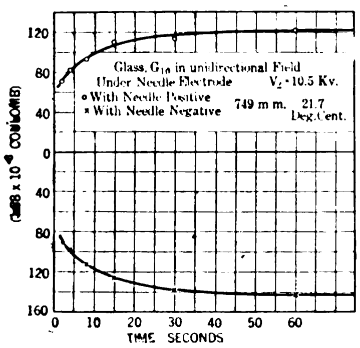

Fig. 19

(*d*) *Effect of Time on the Accumulation of Charge.* Time is no doubt one of the important factors affecting the amount of the accumulation of charge on the dielectric. The author made some experiments on the effect of time on the accumulation of charge when the dielectric were placed under the needle point electrode; the results being shown in Fig. 19, 20 and 21. In these curves, the abscissas represent the time in seconds during which the specimen had been subjected to the electric field, and the ordinates the ballistic throws of the galvanometer when the proof plane was placed

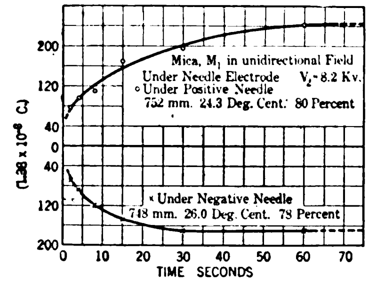

Fig. 20

on the dielectric surface immediately after the field had been taken away. It seems that the resistivity (especially surface resistivity) of the material is the main factor for giving the characteristic form of the curves.

In alternating field, the effect of time is very peculiar especially when the field is of such a value that the accumulated charge just changes its sign from negative to positive. It seems that it takes a certain time to change the condition of the surface so that the positive charge makes its appearance, as shown in Fig. 2.2

(*e*) *Effect of Surface Condition.* From the above experimental results it is conceivable that the free charge is accumulated on the dielectric through the direct action of the field and also the action of the ions in air, and the latter effect will predominate over the former when there is sufficient supply of ions, that is to say, when corona starts at some point in the field and the access to the dielectric is allowed for the ions. Hence, in the latter case, the condition of surface would affect the accumulation of free charge. The experiments in this line, however, cannot give confirmatory results on account of the inaccuracy of the measurement and the great difficulty in eliminating the other disturbing effects.

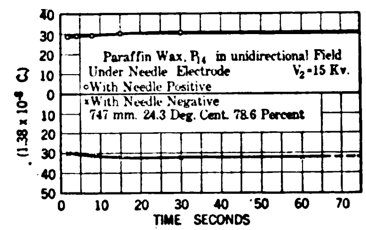

Fig. 21

The only remarkable result which could be definitely observed, is the effect of paraffin wax. When a glass slab was covered with a thin layer of paraffin wax, the accumulation of charge was reduced to a considerable extent, while shellac varnish had practically no effect, as shown in Figs. 23 and 24. The author could not find any remarkable difference in the accumulating charge between smooth and matt surfaces of the same beeswax specimen.

(*f*) *Decay of Accumulated Charge.* It is obvious that the accumulated charge on the dielectric in an intense field will finally disappear after the field is

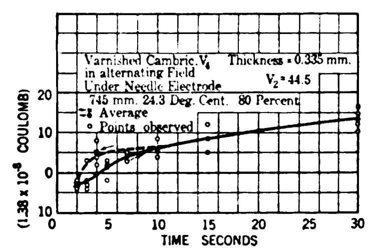

Fig. 22

taken away, but the rate of decay is different to a great extent for the various materials. For example, the charge in oil disappears in a few seconds so that the measured quantity would be far less than that when the field is acting. Very probably this is because of the greater mobility of ions in oil than in solid dielectrics. In glass, mica, varnished cloth and bakelite, the charge will entirely disappear in half an hour or an hour. In these cases, the surface leakage would be an important factor in causing the decay of charge. In paraffin wax, on the other hand, the accumulated charge will not disappear in a short time. It was observed that two months after electrification in electric

field, we had a certain amount of charge on the wax even when the slab had been covered on both sides with tin foils which had been perfectly grounded. Because of this fact, we were obliged to prepare many specimens to test the properties of the wax in its neutral state.

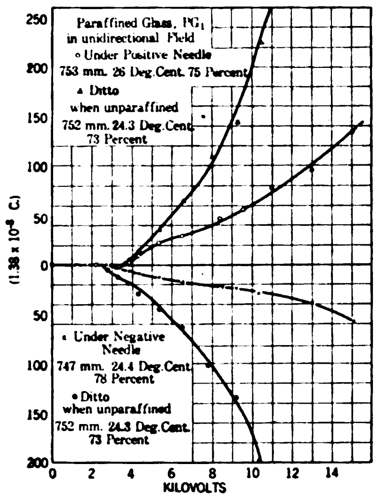

FIG. 23

It is regretted that there was not time enough to make any quantitative measurement on the decay of accumulated charge, though the author made some observations on the current leaking from the dielectric after it had been heavily electrified in an intense field under needle electrode. The curves shown in Fig. 25 are typical ones.

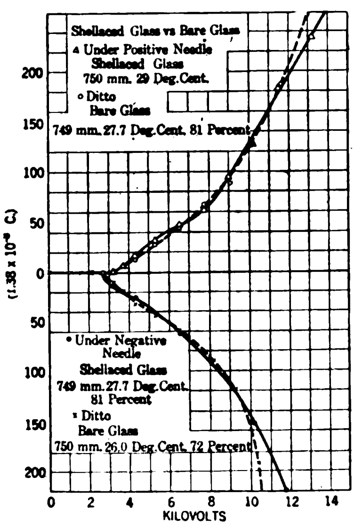

FIG. 24

(*IV*) *Behavior of Porcelain Bushings in Actual Use.* Now it is very important to test the dielectric when it is in actual use as high-voltage insulation. In the high-voltage laboratory of Tokyo Imperial University, we have a 500-kv. testing transformer made by Shibaura Engineering Works. Its bushing was, however, supplied by General Electric Company. This bushing is of the oil-filled type and its outer shell is made of porcelain. A skeleton drawing of it is shown in Fig. 28.

To test the accumulation of charge on the surface of the bushing, the same method was used as above, the only difference being the use of the proof plane made of lead plate, which could be easily shaped

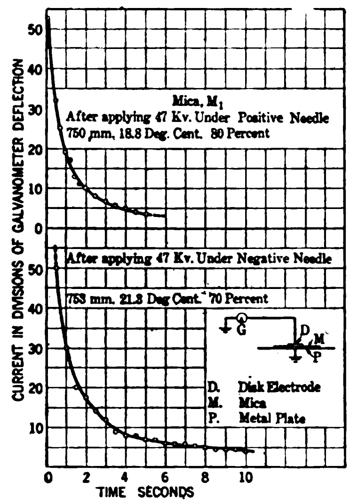

FIG. 25

so as to conform to the curved surface of the bushing. No conductor was connected to the top of the bushing, the electric field being produced by the transformer itself. The field was applied for one minute and then removed by opening the primary switch of the transformer or sometimes by opening the field switch of the alternator feeding the transformer.

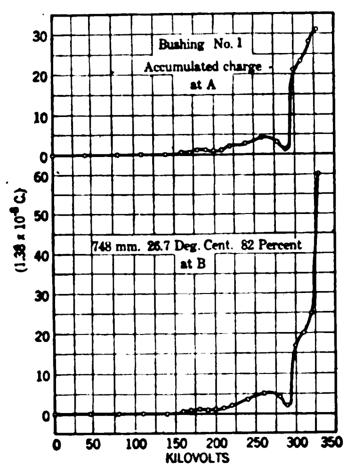

FIG. 26

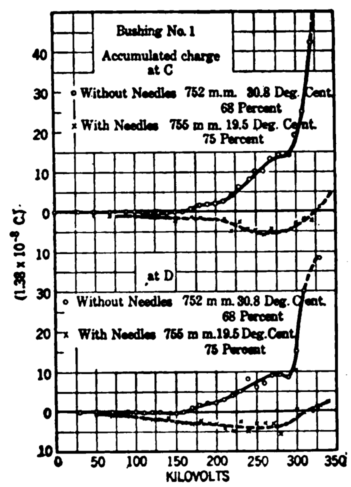

FIG. 27

The measurements of accumulated charge were made on the various parts of the surface of the bushing, the valleys as well as the ridges of the corrugation. But the typical results only are shown here in Figs. 26 and 27. In comparatively weak field, the charge accumulated was negative and it became positive as the field was increased. The appearance of a minimum value at about 290 kv. was found to be due to the starting of corona discharge from the grounded

conductors which happened to be near the bushing. On repeating the test with these conductors removed, the minimum disappeared and it was found that the surrounding conductors had a considerable effect upon the accumulation of charge, especially when the corona discharge therefrom could supply ions to the air surrounding the bushing. To ascertain this fact, we carried out another test in which eight needle points were placed symmetrically around the bushing. The relative position of each needle to the bushing was

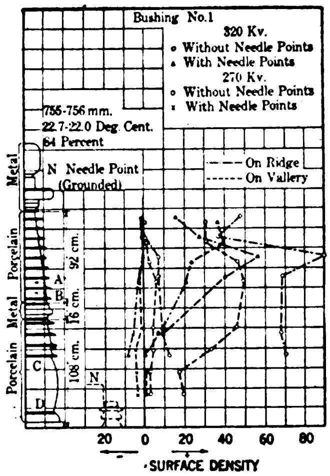

Fig. 28

as shown in Fig. 28, and they were all perfectly grounded. Then it was found that the accumulation of negative charge was increased and consequently the accumulation of positive charge was thereby suppressed to some extent, as shown in Fig. 27 and 28. In Fig. 27, the dotted curves were obtained from the measurement when the needle points were placed around the bushing. In Fig. 28, the abscissa represents the average surface density, and the ordinate the spot of observation. Each mark is connected by a broken or chain line to distinguish one series of the results from another. We can notice the remarkable effect of the needle points especially on the lower part of the bushing.

Our test was further extented to the porcelain bushings made by A. E. G. in Germany and the suspension insulators made of porcelain and boloporcelain, and it was observed that they behaved likewise in electric field of high intensity.

Another remarkable result was that relating to the effect of surface condition on the flash-over voltage. The A. E. G. bushing shown in Fig. 29, has a flash-over voltage of 161 kv. in normal conditions and the arc-over is preceded by the creeping spark on the lower part of the bushing, that is, *C* in Fig. 29. When, however, the lower part of the surface *C* was covered with a very thin film of paraffin wax as shown by hatching in the diagram, the flash-over voltage was raised up to 176 kv., that is, nearly 10 per cent higher, and the initial creeping spark disappeared except for the uniform glow over the lowermost part of the surface. This flash-over value is about the same as that of the post insulator which is exactly of the same form as the bushing.

When the same part of the surface was oiled (ordinary transformer oil), the flash-over voltage was raised up to 165 kv., and the initial surface creepage was also suppressed, but in this case, the continued exposure to a voltage near flash-over value caused the reappearance of the creeping spark.

3. Accumulation of Charge on Insulated Conductors in Electric Field of High Intensity

When the author was carrying out some high-voltage experiment using a static oscillograph, he found erratic shift of the zero point of the oscillograph. After painstaking investigation, it was found that this phenomenon was due to the accumulation of charge on the condensers which were used as multiplier of the instrument, all being connected in series so that each coating of intermediate condensers was insulated from the ground as well as high-voltage source. An idea, then, readily occurred to test the accumulation of charge on the cap and pin of the suspension insulators when they are used for suspendering high-voltage conductors and connected in series as is usually the case. If a considerable quantity of charge be accumulated on the caps and pins of the insulators, the electric stress distribution along the string of the insulators will be obviously much more favorable for flash-over than that determined theoretically from the

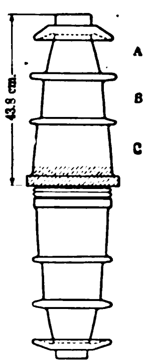

Fig. 29

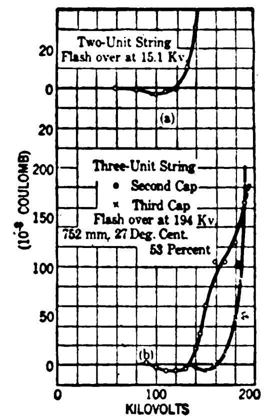

Fig. 30

charging current, *i. e.*, the capacitance between the cap and pin of each unit and the capacitances to earth and the conductor or leakage capacitances.

Of course, it is hardly possible to measure the potential or charge in working condition, and therefore the accumulated charge was measured by a ballistic galvanometer immediately after removing the alternating e. m. f. which had been applied upon the insulator string for 30 seconds. The alternating high voltage was always controlled on the primary of the testing transformer.

The results thus obtained are not very consistent with each other, but it is certain that the quantity of the charges accumulated on the caps and pins of the insulators is not so small that the potential due to these charges only is negligible as compared with the potential distribution due to the applied alternating e. m. f.

The results are shown in Fig. 30, in which the abscissa is the applied e. m. f., and the ordinate the accumulated charge.

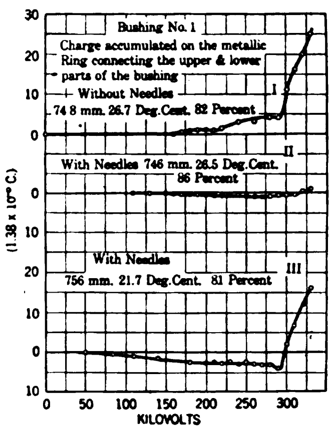

Fig. 31

The potential of the caps of the insulators due to the measured charge can be calculated if the capacitance of each unit be known. According to our measurement, the average capacitance of each unit tested was about 0.006 $\mu.\mu$.f. (0.006×10^{-12} farad).

Assuming the capacitance of each insulator to be the same and leakage capacitances negligible, the following results were obtained for the case in Fig. 30 b, after 190 kv. was applied on the string consisting of three units.

The potential of the second cap = 27,000 volts.
The potential of the third cap = 27,000 volts.

The pin-type insulator consisting of more than two shells may be considered electrically as the condensers in series, the cement layers being the coatings of the condensers. Hence, on placing the insulator in intense field, the charge will be accumulated in each cement layer. This fact was also experimentally verified just before the author's departure from Japan.

It is a well-known fact that one who touches the condenser-type bushing after it has been used is liable to get a heavy shock, if he is not cautious enough to ground the conducting layers before he touches.

Now it is very important to know why the charge is accumulated on insulated conductors when placed in intense field. At first the author had considered that the charge might be accumulated by unidirectional corona discharge from insulated conductors, and carried out some experiments to verify it. But it was not successful, and he found that there must be also another cause. Later on, the author found the accumulation of free charge on dielectric in alternating field, and now has a view that the charge on the insulated conductor is in some cases mainly that which has drifted from the dielectrics in contact with the former.

As stated in preceding paragraphs, the accumulation of charge on dielectrics depends largely upon the corona discharge at some place in the electric field and also the accumulation of charge on insulated conductors depends upon the same factor. The latter fact may be to some extent illustrated by the curves in Fig. 31, which is the result of test on the metallic ring connecting the upper and lower parts of the bushing shown in Fig. 28. The curve I corresponds to the case where the curves in Fig. 26 were obtained, and II and III to the case where needle points were placed around the bushing in two different atmospheric conditions specified on the same sheet. As may be readily seen, there is a characteristic similarity between the curves in Fig. 31 and the curves in Fig. 26 and 27.

The decay curve in this case is shown in Fig. 32, which is very interesting. The ordinates of this curve represent the ballistic throws on connecting the ring to the galvanometer, the other terminal of which was grounded. The ring was grounded for five seconds through the galvanometer and then insulated for 25 seconds. The second reading of ballistic throw was then taken, and the same cycle of process was repeated. The abscissa represents the time elapsed from the instant at which the first reading had been taken to the time of observation. Though the character of this curve resembles the ordinary dielectric absorption curve, it differs from the latter in one respect that the ratio of charge at subsequent discharge to that at the preceding discharge is far greater than in

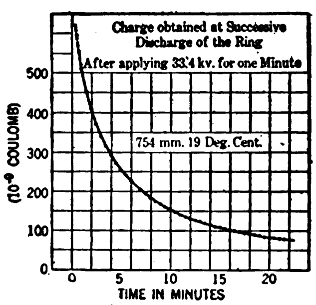

Fig. 32

the latter case. From this point the conclusion is drawn that the charge is mainly that drifted from the porcelain parts of the bushing.

Anyhow, the phenomenon is of technical importance as well as theoretical interest and is worthy of further investigation.

4. Theory of Creeping Discharge Along the Surface of Dielectrics

(a) When the electric field is of high intensity, its distribution is very different, in some cases, from that

when the intensity is low, that is, from that theoretically determined by electrostatics. Because, in intense field, there would be free charge on dielectrics as well as insulated conductors and also the space charge in air—ions—which are constantly in motion, and all these would disturb the original distribution of the field. For example, the vertical component of electric intensity may appear at a point on the surface of dielectrics where only tangential component has initially existed, or the tangential component may appear at a point where there has been the vertical component only.

From the experimental results and the discussion in the preceding paragraphs, it is conceivable that the free charge is caused to accumulate on the surface of dielectric where the vertical component of electric intensity is high. And the appearance of free charge may result in the increase of vertical component in most cases, though it does not always.

Thus, in most cases, the local concentration of dielectric flux will grow up more and more as the intensity increases, and the conditions will become worse progressively. Of course, sometimes, the appearance of tangential component may facilitate the surface creeping discharge.

(b) Owing to the accumulation of free charge and the local concentration of dielectric flux, the ionization of the air film just outside the dielectrics would be very copious, and in such conditions, the conductivity of the air film would be very high. Hence the discharge would finally take place through this layer of air. An evidence of copious ionization near the surface is the fact that there appears glow on the surface just before the occurrence of flash-over when the voltage is gradually raised; this phenomenon being familiar to persons with high-voltage experience.

(c) Owing to the presence of free charge, *i. e.* ions in the surface layer of a dielectric, the conductivity of the dielectric will increase to a value far greater than when uncharged, because it was observed that the similar change took place in resistivity in photoelectric effect on solid insulators.

(d) The surface of dielectrics, though initially absolutely clean and free from moisture, will collect fine dust and perhaps water particles also, when placed in intense field. Very probably the dust or water particles are carrying charge and tend to accumulate on the surface of the dielectric where also exists free charge. The process would be very similar to that of electric precipitation. At all events the result would be the considerable reduction of surface resistivity of the dielectric and together with the above cause, (c), facilitate the surface creeping. The evidence is the fact that after being subjected to high voltage which is just under flash-over value, the surface of the dielectric is very often found to be covered with very fine dust which adheres to the former so firmly that it can be cleaned with great difficulty. The phenomena, I suppose, are familiar with the testers of high-voltage insulators.

3. Goldmann and Kalandyk, *Ann. d. Phys.* 36 p. 589. 1911. It is noteworthy that Goldmann and Kalandyk found the paraffin wax to have the least photoelectric property out of the materials they tested, while the present research reveals that paraffin wax has the least tendency of accumulating free charge on its surface.

5. Important Factors in the Design of High-Voltage Insulation

(a) It would be liable to be misleading to design the high-voltage insulation from the consideration of classical electrostatics only or criticize the insulation already completed from the same standpoint. Because the distribution of electric field, when it is intense enough to produce corona discharge at some spots, would be far from that determined theoretically by ordinary electrostatics, since there would be free charge on the dielectrics as well as on insulated conductors and also space charge in air—ions.

(b) A little consideration on the free charge on dielectrics as well as on insulator conductors and space charge in air will lead to the conclusion that the design of high-voltage insulation should be properly modified according to whether it is to be used in alternating or unidirectional field, and if alternating, whether the frequency is high or low.

(c) Considering that the free charge on dielectrics and insulated conductors depends to a great extent on the ionization of air, it is of extreme importance to determine the best form of dielectrics and conductors, and the best choice of materials with thorough knowledge of the distribution and motion of ions in air so that air may be used as insulation with maximum efficiency.

(*d*) The accumulation of free charge on the dielectrics as well as insulated conductors depends to a great extent on the motion of ions in air. And, therefore, it is very desirable to design the insulation so that the normal component of the electric intensity on the surface of the dielectric is made as small as possible because, the accumulation of charge seems to be very copious where the normal component is high.

It is the present practise in high-voltage insulation to design the shape of the dielectric so as to make its surface conform to the direction of electric field. But such an idea comes from the consideration that if the surface is not tangential to the field, there would be possibility of producing a local concentration of dielectric flux, and not from that above stated. The result is, however, the reduction of the accumulation of free charge, and an efficient insulation was obtained. This fact is most remarkably illustrated by Fig. 27 of Gilchrest's paper (A. I. E. E. p. 584, 1918.)

(e) In some cases, it would be a wise procedure for high-voltage insulation to modify the migration of the ions by special means, such as, air blast, magnetic fields.

The experimental research on this special line is very limited. The author made a few rough tests on the influence of air blast upon the sparking voltage, but owing to the lack of powerful air compressor, the results were not noticeable.

(f) As the last discussion, a few words will be given about the efficacy of corrugations on the surface of the dielectric in the high-voltage insulation. It is a well-known fact that the flash-over voltage can be raised to a certain extent by giving corrugation to the surface of the dielectric especially when the initial sparking takes place along the surface, and also that the improper design of corrugation is not only of no use in raising the flash-over voltage but sometimes results in reduction of flash-over value. The idea prevailing among designers of high-voltage insulation is that the corrugation, rainsheds, or skirts are efficient because the leakage distance (creepage distance) is thereby lengthened and they keep certain parts of the surface dry in stormy weather. Another function is, the author thinks also to modify the moving paths of the ions, and to prevent them from drawing near to the uninjured surface of dielectric or rushing into the other part of air which is playing the most important role in sustaining the electric stress. The most important one of its functions would, howver, be to insert at a certain part of the creepage path an intact zone, that is a zone in which there is no normal component of electric intensity, and therefore, there is least possibility of accumulation of charge. The air just outside such a zone would have a strength against electric stress out of proportion to that of the air film at the other part of the dielectric. So the creeping discharge will be checked here and in consequence the flashover voltage would become somewhat higher. The evidence is the author's observation that the accumulation of fine dust on the surface in intense field is almost imperceptible on the zone, where the field is nearly tangential to the surface, when testing the porcelain bushing shown in Fig. 29.

Though now we have not experimental results enough to support the above statement, it is clear that the thoughtful design of the corrugation is of vital importance in high-voltage insulation, and improper design will not only be ineffective but detrimental for the purpose. It is obvious that the most important factors in the design are the curvature, the thickness, and spacing between the successive ridges.

ACKNOWLEDGEMENT

I have much pleasure, in conclusion, in expressing my best thanks to Prof. H. Nagaoka, Prof. H. Ho and Prof. T. Kujirai of the Tokyo Imperial University for their constant and kindly interest throughout the course of the present research, and also to Prof. Harris J. Ryan of Leland Stanford Junior University for his kindness in carrying out the radio-frequency experiment with me and his valuable criticism and careful revision during the preparation of the paper.

The present research was made in connection with the Physicochemical Research Institute of Japan and the funds for it was supplied by the Institute.

ENGINEERING SERVICE FOR BUSINESS

The head of the Bureau of Chemistry recently obtained authority from the Secretary of Agriculture to organize an Engineering Service for Business under his direction.

The following is quoted from the official statement given out by Dr. Carl L. Alsberg, Head of the Bureau of Chemistry:

The new office is engineering in its powers and personnel. Its function is a business service. It will act as the go-between from science to industry. A force of trained engineers will take up each fresh project as fast as it has passed the experimental stage in the Government laboratories, and attempt to develop its commercial possibilities. It offers, free, a service similar to that which a mining engineer performs for an investor who engages him to report on a gold mine. It will furnish reports covering everything from the source and availability of the raw material supply, to plans on the nature of the machinery needed, size of the plant, capacity of plant, cost of production and market demand for the finished material. In looking over the prospect for getting a leather substitute from a waste material, for instance, the manufacturer need not rely on his own estimates or upon the records of what the process has done on a laboratory scale. He can get reliable quantity production figures from the Office of Development Work, providing only that the process of discovery originated in the Bureau of Chemistry.

The office is a long step toward business efficiency. It talks the language of the investor, it knows his problems, and its officers are well in the forefront of modern industrial development. On the other hand it helps the Government chemist himself by popularizing his process—a thing he is often unable to do for himself. Trained and specialized in the details of his profession he is often unprepared to launch his discoveries on the sea of business. This the new office will do for him through the agency of a force especially prepared to do that very thing.* * * * For the present the work will be confined to discoveries made in the Bureau of Chemistry.

The new office is to be under the direction of David J. Price who has done a great deal of research work, notably in reducing dust explosions. The National Service Department of Engineering Council is in close touch with the work of this Bureau and is prepared to assist engineers who want special problems taken before the new Bureau.

Studies in Lightning Protection on 4000-Volt Circuits—II.

BY D. W. ROPER

Commonwealth Edison Co., Chicago.

The paper continues the investigations described by the author in another paper on the same subject presented before the Institute in June, 1916 which had for its primary object the reconciliation of the differences between laboratory experiments and experience in service.

In the paper an endeavor is made to list the several factors which affect lightning arrester performance and to describe the methods of eliminating these several variables so as to permit the presentation of curves which show the relative merits of the arresters under investigation. The elimination of the several variable factors was accomplished by placing the arresters under practically identical conditions so that no type was at any material advantage or disadvantage on account of the preponderance of the factors which would affect its performance. This was found to be possible for all of the factors except the one relating to density of the arresters, that is, the number per square mile, so that the final curves show the performance of the several types of arresters as affected by their density. These results show that four of the types of arresters are practically identical in their protective value and about 60 per cent as efficient as a fifth type, while the results for the sixth type, being limited to a much smaller number of arresters, and a shorter period of time, do not appear to be conclusive.

1. INTRODUCTION

THE investigations forming the basis of this paper as well as the previous paper[1] on the same subject had as their primary object the determination of the relative merits of the several types of lightning arresters which were installed on the 60-cycle distribution system of the Commonwealth Edison Company in Chicago. The previous investigations had indicated in a general way the several factors which affected lightning arrester performance and also the extreme variability of the distribution and intensity of the lightning storms, from which it appeared that in order to get reasonably accurate results, it would be necessary to accumulate the experience with a large number of arresters over a period of several years. The keeping of systematic records of lightning arrester performance as outlined in the previous paper was, therefore, continued and the manufacturers of the arresters were advised from time to time of the results. These data showed some slight variations from year to year, but the order of merit of the lightning arresters as shown by the figures given in the previous paper was not altered. In the meantime the manufacturers of the arresters had on their part been making investigations and experiments for the purpose of improving their designs, and one of them, as a result of such laboratory experiments, presented a table of figures which he stated represented the relative merit of the various types of arresters. The experience obtained in Chicago, however, did not substantiate the results of the laboratory experiments and placed the arresters in quite a different order. In the hope of reconciling these differences and reaching conclusions, acceptable to all interested parties, regarding the relative merits of the several types of arresters, an investigation was started about a year ago in which the manufacturers cooperated. In the following, the methods used in this investigation and the final results secured are set forth.

To be presented at the Chicago Meeting of the A. I. E. E., November 12, 1920.

1. TRANS. A. I. E. E., 1916, Vol. XXXV, p. 655.

2. DESCRIPTION OF THE SYSTEM

The system of distribution on which these investigations were made is a four-wire three-phase system, with the neutral grounded only at the substations. The normal potential on the distributing mains is 2080 volts between phase and neutral wires. The distribution pole lines are in the alleys, or along the rear lot lines in the center of the block where alleys are missing. Single-phase transformers are used exclusively and are connected between the phase and neutral wires except in the case of three-transformer three-phase installations in which case the common point of

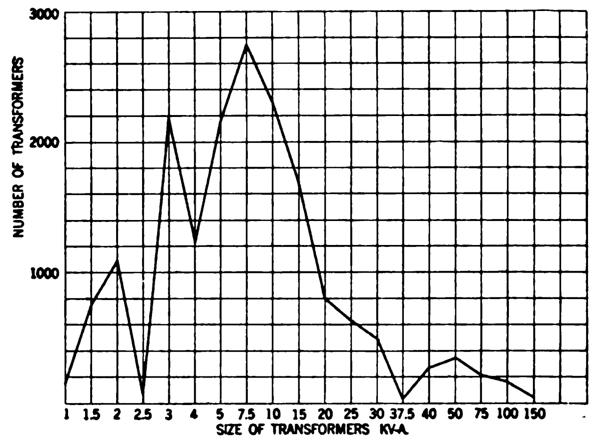

FIG. 1—DIAGRAM SHOWING THE NUMBER OF EACH SIZE OF TRANSFORMER IN SERVICE ON AUGUST 1ST, 1918

the transformer primaries is not connected to the neutral wire. Secondaries of power transformers are connected in delta. Power and lighting customers are supplied from the same primary mains, but the very large customers are connected to a 12,000-volt system. The feeders are all No. 0 wire and the mains No. 6 A. W. G. About 85 per cent of the feeders and 15 per cent of the mains are underground. About 99 per cent of the transformers are on poles and the rest in manholes or in vaults on customers' premises. At single-transformer installations a 2400-volt arrester is connected to the same phase wire as the transformer

and a 300-volt arrester to the neutral wire. Where three transformers are installed for a power service there are three 2400-volt arresters, one connected to each of the phase wires; and one 300-volt arrester is connected to the neutral wire. Arresters are installed in this manner on the same pole with all transformers. The lightning arrester ground consists of one-half inch galvanized iron pipe ten feet long, driven into

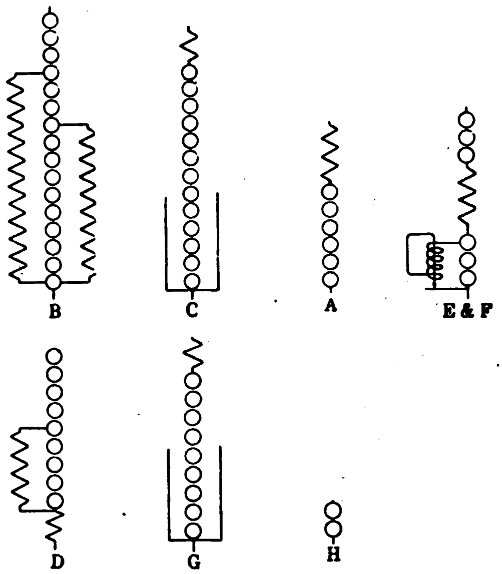

Fig. 2—Electrical Diagrams of the Lihgtning Arresters Used in These Investigations

The gaps are conventional and do not show the actual shape of the gaps on all of the arresters.

Arresters *E* and *A* have identical diagrams and differ principally in mechanical details, the amount of resistance and the length of the resistance rod.

Diagram *G* shows a type which was installed in 1920.

Diagram *H* represents the netural 300-volt arrester installed on the neutral.

the ground at the base of the transformer pole. Secondary circuits are usually less than one block long and the secondary ground is similar to the lightning arrester ground, but is installed on the next pole. On long secondaries there are at least two such ground connections and in addition the neutral wire on the customer's premises in many recent installations is grounded to the water pipes inside of the building. Where there are four primary wires in an alley they are installed on the top arm and the secondaries on the second arm. Where there are only two primary wires the lighting secondaries may be installed on the same arm. More than 80 per cent of our poles are owned jointly with the Telephone Company, and there is a minimum clearance of four feet between the wires of the two companies. In order to regulate the voltage properly, the area supplied by each feeder is divided into three portions corresponding to the three phases, and the single-phase lighting load in each portion is all connected to one phase. Arresters similar to those installed for the protection of transformers are installed on the cable poles where the underground feeders or mains connect with the overhead wires. The distribution system at this time includes about 100,000 poles, 20,000 transformers with a total capacity of about 270,000 kv-a., 6500 conductor miles of overhead primary line wire, 2200 conductor miles of underground cable and 2500 cable poles. The system serves about 400,000 customers.

In Fig. 1 is shown the number of each size of transformers on the line as of August 1st, 1918. This date was selected for the purpose of the calculations, as the number of transformers in service on that date was about the average of the number in the five-year period under investigation. Fig. 2 shows electrical diagrams of all of the lightning arresters used in the investigations. The letters shown on this diagram are consistently used throughout the several tables, diagrams and curves. Fig. 3 shows graphically the number of transformers on the distribution system over a period of years, as well as the percentage of transformer primary fuses blown and transformers burned out by lightning each year. The increase in the percentage of fuses blown during the years 1918 and 1919 was due to causes definitely known to be entirely distinct from lightning, but as some of these fuses were blown during the same day as lightning storms, they were included with fuses blown by lightning because of the impossibility of accurately determining just which fuses were blown by lightning and which by other causes.

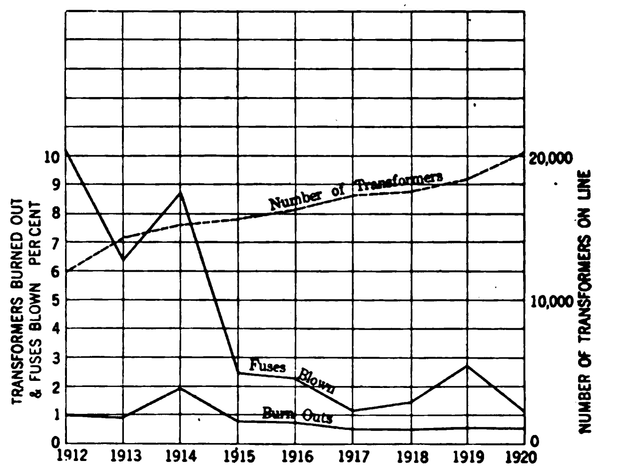

Fig. 3—Graphical Record Showing the Number of Transformers in the Distribution System and the Per Cent of Transformer Troubles Each Year Over a Period of Years

In Fig. 4 is shown the percentage of burn-outs of transformers for each storm during the five-year period and also for the year 1920, the percentages being plotted cumulatively. From these records it will be noted that it is not unusual to have over one-third of the total trouble in any one year due to lightning occur in one or two days. A composite of these curves for the five-year period is shown in Fig. 5, from which it will be noted that on the average, the

lightning is quite uniformly distributed throughout the 4½ months from May 1st to September 15th, and that there is comparatively little trouble outside of this period.

Fig. 6 is an outline map of the portion of the city covered by the distribution system on August 1st, 1918, showing the section lines and the lightning arrester area numbers. These areas will be found to differ from those shown in the previous paper as some changes were made in 1917 for the purpose of trying another type of arrester, a new scheme of protection and incidentally securing a little better distribution of the various types of arresters over the different portions of the city. The shaded areas on this diagram will be referred to later in the paper.

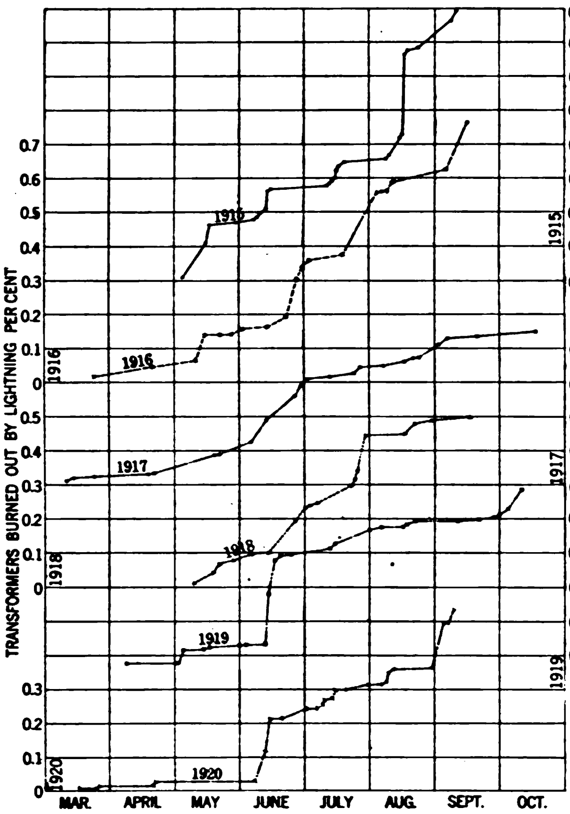

Fig. 4—Diagram Showing the Percentage of Transformers Burned out in Each Storm for the Years 1915-1919 Inclusive

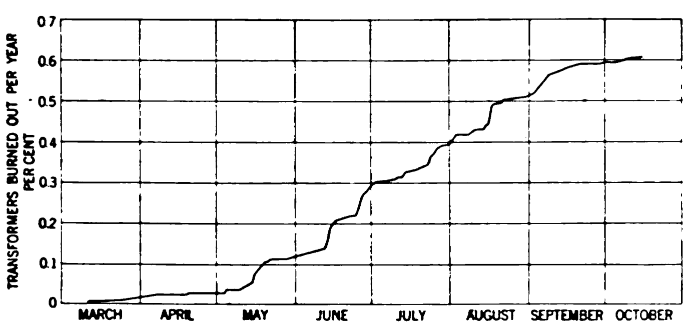

Fig. 5—A Composite Diagram of the Transformer Burn-Outs for Years 1915-1919 Inclusive

3. Preliminary Investigations

From the previous paper and subsequent studies it appears that the factors which might affect lightning arrester performance are as follows:

1. The system of distribution and the grounding of the neutral.
2. Primary terminal boards.
3. The shielding effect of trees, buildings or wires of other companies.
4. The resistance of the lightning arrester ground connection.
5. The maker of the transformer.
6. The size of the transformer.

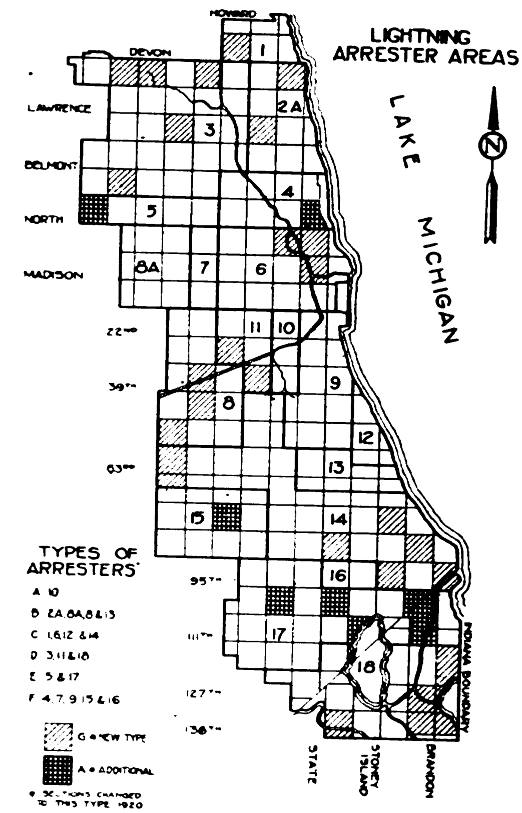

Fig. 6—Outline Map of the City, Showing Section Lines and Lightning Arrester Area Numbers

The lightly shaded areas show the sections in which arrester *G* shown in Fig. 2 was installed in 1920. The heavily shaded portions show the sections in which additional arresters of type *A* were installed in 1920 for the purpose of getting more conclusive information regarding this type.

7. The age and previous service record of the transformer.
8. Variation in the distribution and intensity of the lightning.
9. The density of lightning arresters, that is, the number per square mile.
10. The design of the arrester.

Records were available for the five-year period 1915 to 1919 inclusive and these records were carefully compiled in great detail and arranged systematically so as to set forth all facts which might influence the results. The history of each burnt-out transformer from the date of its purchase to the time of its burn-

out was also assembled and tabulated. In Chicago the same system of distribution is used throughout the entire city and the neutral is grounded at each of the substations from which the circuits emanate, so that all types of arresters, as far as this point is concerned, are installed under identical conditions.

The previous paper describes the earlier experiments which prove the disadvantage of primary terminal boards within the transformer case. As a result of these investigations the practise was established of removing the terminal boards from all transformers which were returned from the lines to the storeroom for any purpose such as changes on account of increased load or discontinuance of service. The number of transformers which returned to the storeroom in this manner during a year was on the average about equal to the number of new transformers added to the system so that the percentage of transformers in service with primary terminal boards was rapidly reduced. It appeared from this investigation that the percentage of transformers with primary terminal boards was so low and the transformers so well distributed over the system that they had no appreciable effect on the relative performance of the lightning arresters.

In laying out the lightning arrester areas which were given in the previous paper, and which are also shown in Fig. 6 in this paper, it was the intention to arrange the boundaries of the areas and to distribute the several types of lightning arresters over the city so as to eliminate variables 3 to 8 inclusive as given in the above list. In order to determine whether this result had actually been secured, the records of the transformer burn-outs due to lightning were carefully investigated in cooperation with the manufacturers of the arresters. The previous paper had indicated the difference in the results as effected by the maker and the size of the transformer. In investigating these points we assumed that if the percentage of burn-outs of any one maker or any size of transformer which had been protected by any type of arrester were not seriously different from the percentage of such transformers protected by that type of arrester to the total on the system, that no type of arrester was at any disadvantage due to unequal distribution of such transformers on the system.

An investigation of the records demonstrated beyond question that the shielding effect of trees or buildings immediately adjacent to the lines considerably reduced the amount of damage on our lines from lightning. This was shown by the following facts:

(a) The percentage of poles in the distribution system shattered by direct strokes is extremely small, being of the order of 1/400 of 1 per cent. This is very much smaller than the corresponding percentage for transmission line poles belonging to the same company in the flat open country in the southeastern portion of the city and is also smaller than experienced in general by companies having transmission lines crossing open country. That there are many direct strokes in every severe lightning storm is shown by the newspaper reports on the day following lightning storms, which record the most severe or unusual cases of damage to trees, church steeples, chimneys, or other portions of buildings and structures.

(b) An investigation of the conditions surrounding the installation of 97 out of 529 cases covered by these investigations where transformers were burned out by lightning failed to reveal a single case in which the primary wires adjacent to the transformer were overshadowed by high trees or buildings immediately adjacent.

By "spot checking" selected portions of each of the lightning arrester areas in cooperation with the representatives of the manufacturers, it appeared, although the shielding effect of trees and buildings was considerable, that as far as could be determined without making a detailed survey and record of the conditions in each block throughout the city, no type of arrester was at any serious advantage or disadvantage on this account.

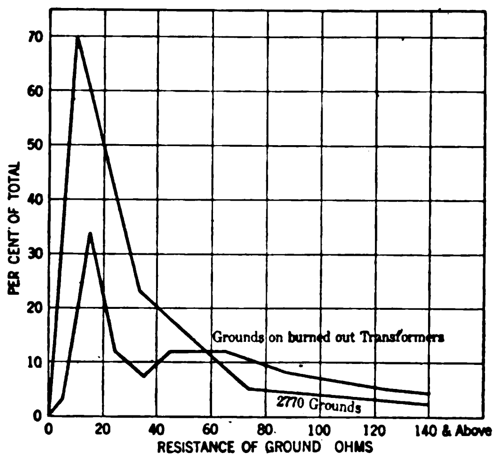

Fig. 7—Results of Tests of Resistance of Grounds

The line showing grounds on burned out transformers was made up from tests on arrester grounds at locations where 97 transformers burned out in 1919. The curve marked 2770 grounds shows the results of tests made in 1917 in cooperation with representatives of the Bureau of Standards.

With the idea that some of the transformer burnouts might have been due to ground connections having a resistance so high as to render the arrester ineffective, the resistance was measured at 97 locations where the surrounding conditions were also noted in detail, and the results are shown in Fig. 7. On the same figure is shown, in a similar way, the resistance of 2770 grounds, both lightning arrester and secondary grounds, which were tested in 1916. It will be noted from this figure that the resistance of the lightning arrester grounds at the points where the 97 transformers were burned out by lightning averaged slightly above the resistance of the much larger number tested three years earlier. It therefore, appears that the burn-outs were not due to particularly bad ground connections

for the lightning arresters at the locations where the transformers burned out.

In the same manner the records and the conditions surrounding the transformer installations were carefully and thoroughly examined to determine the effect of the other points 5, 6 and 7. These investigations included the assembling of the complete history of each transformer that had burned out during the five-year period and the compiling and assembling of all data which might serve to add to the information on the several points. On the completion of the investigation, the representatives of the manufacturers concurred in the decision that none of the arresters appeared to be at any material advantage or disadvantage on account of the first seven variable factors in the above list, and these factors were, therefore, ignored in the further investigation.

There still remains two variables, namely the variability of the lightning, and the density of lightning arresters. In determining the relation between the density of lightning arresters and their performance, a method was discovered of eliminating the effect of the lightning as a variable as described at some length later in the paper.

4. The Effect of Density of Lightning Arresters on Their Performance

A preliminary investigation of the effect of density was made by plotting the density of arresters in each original lightning arrester area against the percentage of burn-outs in that area. The points plotted in this manner were so irregular that they did not permit the drawing of any curve which might be considered as representing the results, but the method appeared to indicate that there was a very marked decrease in the percentage of burn-outs with increase in density which would warrant further investigation along this line. The results also indicated that some further subdivisions of the original lightning arrester areas would be necessary in order to eliminate the lightning as a variable. The manner in which the records were kept enabled this change to be made very readily by using the section (that is, the square mile) as the unit, resulting in an increase in the number of areas from 19 to 192. For each one of these sections there was determined from the records the number of transformers in the section as of August 1st, 1918. As there is an arrester on the same pole with each transformer, and comparatively few cases where there were two transformers connected to the same phase wire on the same pole, the number of transformers in each section was taken as the number of arresters. There was also determined for each section the number of transformer burn-outs and primary fuses blown by lightning during the five-year period and the actual area covered by the line. This latter quantity was determined by going over the large scale maps of the distribution system and assuming that a line through the center of the block covered the width

TABLE I

DATA FOR DETERMINING THE EFFECT OF DENSITY OF ARRESTERS ON THEIR PERFORMANCE

The types of arresters are indicated in Fig. 2, the area numbers are shown in Fig. 6, the section numbers in Fig. 11. The stars (*) indicate the sections in which the type of arrester was changed in 1917. Figures for the average curve are taken from this table but due allowance for this change was made in plotting the curves for the individual arresters.

Present type of arresters	Area number	Section number	Number of transformers in section	Number of burn-outs in section	Number of fuses blown in section	Area actually covered by lines	Density of arresters per square mile	Average per cent burn-outs per year
C	6	325	4	0	0	0.45	9	0.
D	18 *	987	1	0	0	0.09	11	0.
D	18 *	1067	4	0	1	0.13	31	0.
D	18 *	1107	1	1	0	0.03	33	20.
D	3 *	103	3	0	0	0.09	33	0.
D	18 *	1025	7	0	0	0.18	39	0.
D	3 *	99	7	0	1	0.17	41	0.
C	1 *	61	1	0	0	0.02	50	0.
D	18 *	1059	3	0	2	0.05	60	0.
D	3 *	97	5	0	2	0.08	62	0.
F	15 *	751	8	1	2	0.13	62	2.50
D	3 *	237	6	0	0	0.09	67	0.
E	45 *	271	20	2	11	0.30	67	2.
D	18 *	1065	19	2	0	0.27	70	2.11
F	9	447	5	0	0	0.07	71	0.
C	14	697	6	1	1	0.08	75	3.33
F	15 *	725	7	1	4	0.09	78	2.86
E	17	899	30	4	9	0.38	79	2.67
C	14	815	15	0	2	0.18	83	0.
F	15 *	753	26	3	4	0.31	84	2.31
C	14	651	63	5	10	0.74	85	1.59
D	3 *	95	44	4	5	0.52	85	1.82
C	6	365	18	1	0	0.21	86	1.11
B	8	517	26	0	3	0.29	89	0.
E	17 *	945	17	3	2	0.19	90	3.53
D	3 *	105	22	3	3	0.24	91	2.73
D	3 *	136	23	4	2	0.23	100	3.48
B	8 *	559	10	3	6	0.10	100	6.00
F	15 *	809	3	0	0	0.03	100	0.
E	17	901	9	0	2	0 09	100	0.
D	18 *	1105	4	0	1	0.04	100	0.
C	14	819	47	9	14	0.46	102	3.83
E	5 *	273	32	2	12	0.31	103	1.25
E	17 *	947	33	1	5	0.32	103	0.61
D	18 *	1017	60	6	14	0.55	109	2.
E	17	893	65	12	29	0.59	110	3.69
B	8 *	601	33	2	7	0.30	110	1.21
D	3 *	168	22	2	6	0.20	110	1.82
C	14	817	31	1	2	0.28	111	0.65
C	14	865	20	2	11	0.18	111	2.
D	3 *	235	48	4	5	0.43	112	1.67
C	1 *	41	47	1	9	0.42	112	0.42
C	14	653	86	4	13	0.77	112	0.93
D	3 *	94	9	2	0	0.08	113	0.44
D	3 *	139	25	4	3	0.22	114	3.20
D	3 *	239	24	0	1	0.21	114	0.
D	3 *	137	62	5	11	0.54	115	1.61
E	17	857	51	6	16	0.44	116	2.35
F	15 *	727	52	5	6	0.45	116	1.92
F	16	863	29	4	4	0.25	116	2.76
E	17	935	22	2	6	0.19	116	1.82
D	3 *	199	41	4	4	0.35	117	1.95
C	14	649	41	8	8	0.35	117	3.90
D	18 *	1019	25	1	6	0.21	119	0.80
C	14	701	42	2	5	0.35	120	0.95
E	17	897	36	6	31	0.30	120	3.33
B	8	515	12	1	0	0.10	120	1.66
F	15 *	723	6	1	2	0.05	120	3.33
E	17	933	35	2	7	0.29	121	1.14
D	3 *	203	88	7	13	0.73	121	1.59

TABLE I—*Continued*

Present type of arresters	Area number	Section number	Number of transformers in section	Number of burn-outs in section	Number of fuses blown in section	Area actually covered by lines	Density of arresters per square mile	Average per cent burn-outs per year
C	14	699	45	2	9	0.37	122	0.89
D	3*	201	53	4	4	0.43	123	1.51
B	8A	394	32	0	8	0.27	123	0.
E	17	975	14	2	5	0.11	127	2.86
E	17	855	35	6	22	0.27	130	3.43
C	14	811	92	4	11	0.71	130	0.87
E	17	895	63	7	14	0.48	131	2.22
C	14	763	105	4	13	0.80	131	0.76
D	3*	171	124	7	14	0.94	132	1.13
C	14	759	104	5	10	0.79	132	0.96
D	3*	241	62	5	8	0.47	132	1.61
C	6	405	16	0	1	0.12	133	0.
B	8*	561	109	4	6	0.83	133	0.73
C	14	813	44	0	9	0.33	133	0.
B	8*	603	39	3	19	0.29	134	1.54
E	5*	275	80	2	12	0.59	136	0.50
E	17	937	68	3	28	0.50	136	0.88
D	3*	169	109	6	11	0.81	136	1.08
E	17	859	22	1	3	0.16	137	0.91
B	8A	314	49	1	7	0.38	137	0.35
E	17	977	107	13	24	0.78	137	2.43
F	16	861	36	3	3	0.26	138	1.66
C	1	65	88	2	3	0.63	140	0.46
B	8A	605	71	3	10	0.49	145	0.86
D	3*	141	76	1	12	0.52	146	0.26
C	12	571	115	2	7	0.78	148	0.35
B	8	519	75	3	8	0.49	153	0.80
D	3*	205	137	6	26	0.89	154	0.88
E	17	939	72	6	22	0.46	156	1.66
C	14	755	128	2	18	0.81	158	0.31
D	3*	143	62	0	7	0.39	159	0.
C	14	757	119	2	6	0.75	159	0.34
C	1*	63	106	4	4	0.66	160	0.75
C	14	765	70	3	9	0.43	163	0.86
C	1	43	30	0	2	0.19	163	0.
C	14	733	74	1	6	0.45	164	0.27
C	14	703	71	3	8	0.43	166	0.85
D	3*	207	139	1	25	0.84	167	0.14
D	3*	173	161	7	19	0.96	167	0.86
B	8A	315	116	2	10	0.72	167	0.33
B	2A	145	120	8	16	0.73	167	1.29
B	2A	109	148	2	8	0.86	172	0.27
C	14	821	85	3	11	0.49	174	0.71
D	3*	243	171	2	15	0.98	174	0.23
C	14	737	54	1	5	0.31	175	0.37
D	18*	1099	14	3	1	0.08	175	4.28
F	4	287	132	0	5	0.75	176	0.
E	17	907	74	3	8	0.42	176	0.81
C	14	823	16	0	3	0.09	177	0.
F	9	445	25	1	2	0.14	179	0.80
B	2A	107	47	2	7	0.29	179	0.77
B	8	475	106	2	15	0.59	180	0.38
C	6	367	9	0	1	0.05	180	0.
B	8	435	85	4	10	0.47	180	0.84
E	17*	905	45	1	14	0.25	180	0.44
F	7	357	140	0	8	0.77	181	0.
D	3*	175	161	7	16	0.88	183	0.87
C	14	655	132	11	17	0.72	184	1.67
C	14	735	32	2	1	0.17	188	1.25
F	7	317	176	2	10	0.93	190	0.23
E	5*	277	166	4	15	0.87	191	0.48
C	14	705	176	2	8	0.91	193	0.23
C	12	663	70	1	3	0.36	195	0.29
C	6	403	166	1	8	0.83	199	0.12
B	8	661	123	0	7	0.62	199	0.

TABLE I—*Continued*

Present type of arresters	Area number	Section number	Number of transformers in section	Number of burn-outs in section	Number of fuses blown in section	Area actually covered by lines	Density of arresters per square mile	Average per cent burn-outs per year
D	18*	1015	18	0	4	0.09	199	0.
C	6	407	2	0	2	0.01	200	0.
B	2A	215	77	2	7	0.38	202	0.52
B	8A	395	185	2	12	0.94	202	0.21
B	13	709	65	1	1	0.32	203	0.31
F	4	247	120	5	3	0.59	204	0.83
D	11*	521	156	5	30	0.76	205	0.64
C	12	615	172	1	7	0.84	207	0.12
C	6	319	156	6	10	0.76	208	0.77
C	14	607	165	4	30	0.79	208	0.48
C	14	657	203	6	12	0.97	209	0.59
E	5*	279	201	5	27	0.96	210	0.50
B	8A	354	105	1	3	0.50	210	0.19
C	14	867	146	8	21	0.69	212	1.10
F	9	485	119	3	9	0.55	214	0.50
F	4	245	205	2	10	0.95	215	0.20
C	14	761	170	7	19	0.79	216	0.82
B	8	437	216	1	13	0.99	218	0.09
B	13	659	196	4	14	0.89	221	0.41
B	2A	211	218	2	7	0.99	221	4.18
C	14	609	84	2	11	0.38	221	0.48
B	8A	355	122	0	4	0.55	221	0.
B	2A	177	209	4	11	0.97	221	0.37
F	9	525	152	9	17	0.68	224	1.18
D	18*	979	142	6	15	0.63	226	0.85
F	9	613	159	0	5	0.79	227	0.
F	9	610	98	6	9	0.43	228	1.23
C	1*	39	7	1	1	0.03	231	2.86
F	7	397	188	2	5	0.80	235	0.21
B	8	477	221	2	19	0.94	235	0.18
B	13	711	112	1	5	0.47	238	0.18
D	11*	441	179	4	9	0.75	238	0.45
B	2A	147	193	0	9	0.82	238	0.
F	9	569	235	1	8	0.97	242	0.09
C	14	563	68	3	10	0.28	243	0.88
C	12	641	32	0	2	0.13	246	0.
A	10*	523	118	3	14	0.47	249	0.51
B	2A	213	227	1	10	0.94	250	0.09
F	4	281	238	5	13	0.95	250	0.42
C	14	869	53	1	4	0.21	252	0.39
F	4	251	129	2	4	0.51	253	0.31
F	9	611	129	4	19	0.51	253	0.62
B	2A	179	204	3	4	0.80	255	0.29
D	3*	209	161	2	11	0.63	256	0.25
A	10*	443	203	3	11	0.78	259	0.30
D	11*	479	129	3	9	0.49	263	0.47
A	10*	483	153	1	13	0.57	269	0.13
C	14	731	108	1	4	0.39	277	0.19
C	6	399	263	3	16	0.95	277	0.23
F	4	283	267	1	18	0.96	278	0.08
F	9	567	224	6	22	0.79	286	0.54
D	11*	439	183	0	11	0.64	286	0.
F	4	249	287	7	17	0.99	289	0.49
C	6	323	183	2	9	0.63	291	0.22
C	6	321	284	10	23	0.95	298	0.70
C	12	665	6	0	0	0.02	300	0.
C	6	359	226	2	15	0.75	303	0.18
B	13	707	119	1	6	0.39	305	0.17
F	4	285	243	7	15	0.77	316	0.58
C	6	363	264	7	12	0.82	322	0.53
B	11*	481	113	0	8	0.35	323	0.
C	6	401	315	5	20	0.95	325	0.32
C	6	361	318	5	27	0.95	335	0.31
B	13	687	98	0	2	0.29	338	0.
C	14	565	21	0	3	0.06	350	0.
E	17	941	4	0	1	0.01	400	0.
F	9	527	32	2	0	0.05	640	1.25
Total & Averages			17,529	529	1,702	92.88	190	0.60

Total number of Section 192

of the block. (This width varies in the different portions of the city from about 250 ft. to over 600 ft. and averages approximately 400 ft.) From these figures can be calculated the percentage of burn-outs in any section or group of sections. The data with the sec-

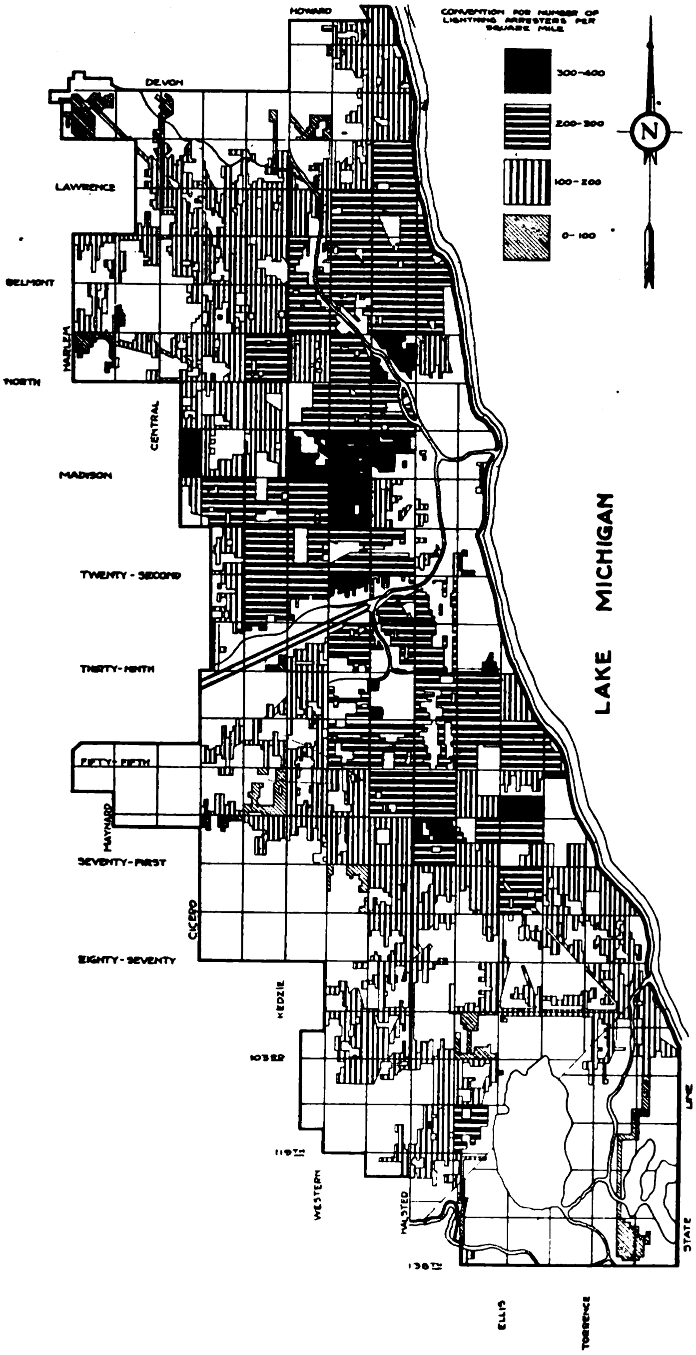

FIG. 8—OUTLINE MAP OF CHICAGO, SHOWING SECTION LINES AND AREA ACTUALLY COVERED BY DISTRIBUTION SYSTEM
Density of shading indicates the density of lightning arresters.

tions arranged in the order of density of arresters are shown in Table I.

The data in this table and other data regarding the system are shown graphically in several drawings which give a better idea of the conditions than can be obtained from tables of statistics. In Fig. 8 is shown an outline map of the city on which are shaded the areas actually covered by the lines, the number of arresters per square mile being indicated by the density of the shading. The distribution system extends into 192 sections covering 163.25 square miles within the city, while the area actually covered by the lines, determined in the manner above described is 93.49 square miles. As there were 17,529 transformers on the lines on August

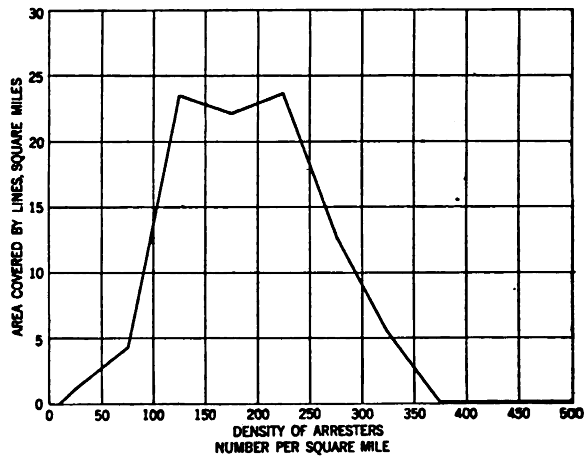

FIG. 9—DIAGRAM SHOWING THE AREA ACTUALLY COVERED BY THE DISTRIBUTION SYSTEM FOR VARIOUS DENSITIES OF ARRESTERS

1st, 1918, the average density of arresters is thus 187 per square mile.

Fig. 9 shows these data in another manner, from which figure it will be noted that in the larger portion of the area covered by the distribution system, the density of arresters ranges between 100 and 300 per

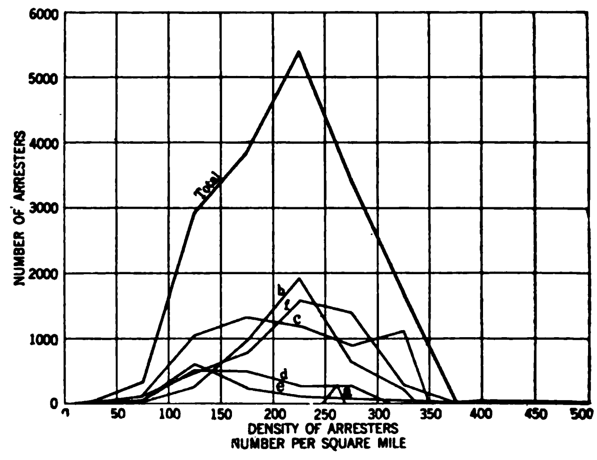

FIG. 10—DIAGRAM SHOWING FOR VARIOUS DENSITIES OF ARRESTERS THE NUMBER OF EACH TYPE OF ARRESTER AND OF ALL TYPES CONNECTED TO THE DISTRIBUTION SYSTEM

square mile. The number of arresters for various densities and for each type of arrester is shown in Fig. 10. In this drawing it will be noted that arrester *A* was installed in sections with a very narrow range in density. The section numbers given in the third column in Table I are shown in Fig. 11. The stars preceding the section numbers in Table I indicate the

sections in which a change in the type of lightning arrester was made preceding the lightning season of 1917 for the purpose of permitting the installation of an additional type of arrester and securing a better distribution of the several types of arresters in different portions of the city.

In Fig. 12 there has been plotted for each section the density of arresters as shown in the eighth column

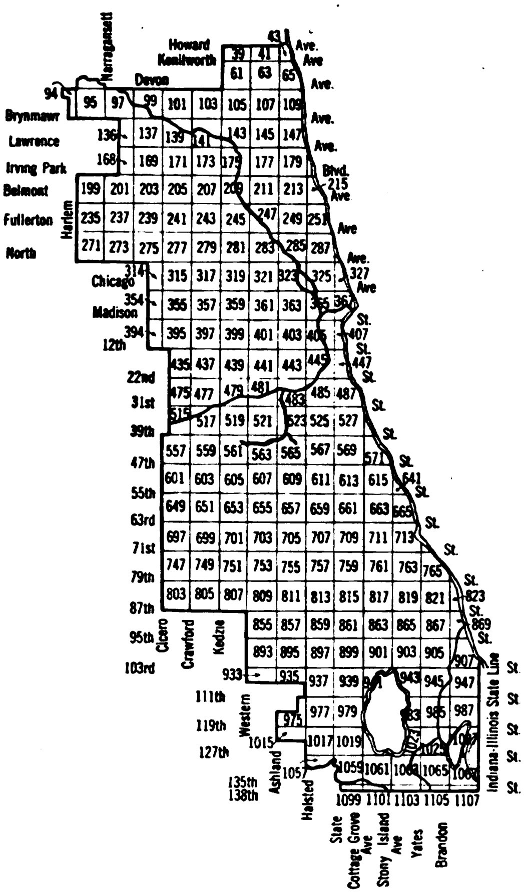

Fig. 11—Outline Map of Chicago, Giving the Numbers Assigned to Each of the Sections as Shown in the Third Column of Table I

in Table I and the average per cent of burn-outs as shown in the last column. The final curve for all arresters showing the variation in the performance of arresters with their density is also shown in the same figure, but the curve cannot be drawn directly from the points shown in this figure because these points, representing different areas and different numbers of transformers, are not of equal weight. Nothing in the tables or records shows the wide variation in the distribution and intensity of the lightning quite so well as the plotting of these points in Fig. 12. Out of the 192 sections it will be noted that in about one-sixth of them the points are on the line of zero burn-outs, showing that there were no burn-outs whatever in these sections during the five-year period.

In order to secure points of equal weight for the purpose of drawing the curve, it was decided to have each point represent the experience with the same number of transformers. At first trial it was agreed to assemble the data so as to get 18 points, each of which would therefore include the data from approximately 1000 transformers. The data for the first point were obtained by starting at the top of Table I and including enough sections to get a total of about 1000 transformers. Then the figures showing the area covered and the number of burn-outs was totaled for these sections, from which could be determined the average density of the arresters and the average per cent of burn-outs for this group of transformers. This was equivalent to taking a vertical band of Fig. 12 which would include enough points to make a total of 1000 transformers and finding one point to represent the average experience for the entire band. In the same way the other 17 points were calculated and are shown plotted to logarithmic coordinates in Fig. 13. The use of logarithmic coordinate paper was adopted for the purpose as it was found to greatly facilitate the work. There was some question as to whether the number of points selected for assembling the data in this manner had any effect on the resulting curve, but it appeared that if practically the same line were obtained by using a different number of points that there would be no serious error in the method. The same data were therefore assembled in a similar manner in 7 points, 4 points and 2 points and the results are

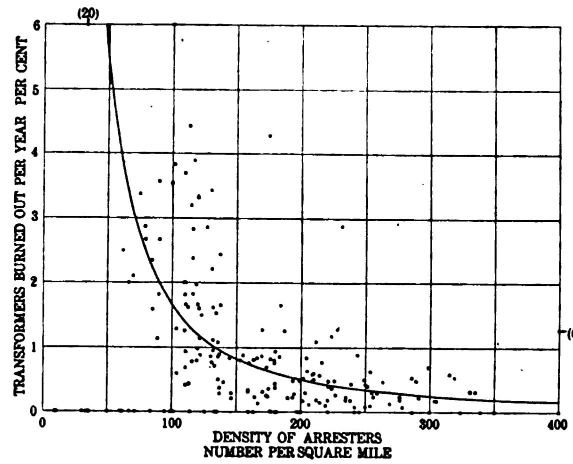

Fig. 12—Diagram Showing for Each of 192 Sections the Average Per Cent of Transformer Burn-Outs Due to Lightning for the Five-Year Period Plotted Against the Density of Arresters

The curve shows for all types of arresters the final determination of the relation between density of arresters and transformer burn-outs due to lightning. The curve cannot be plotted directly from the points shown in the figure as they are not of equal weight.

shown respectively in Figs. 14, 15 16. After a number of attempts to draw curves through these points in the several figures, it was found that a straight line would properly represent the results just as well as any curve which might be drawn; and it was, therefore, assumed that the curve when drawn on logarithmic coordinate paper was a straight line, which is equivalent to assuming that the relation between the quantities is an exponential function. In each of the four figures the

full line is determined by the points in that figure and the dashed line is the average of all of the four. It will be noted that the variation of the points through the straight line decreases as the number of points decreases, or in other words, as the number of trans-

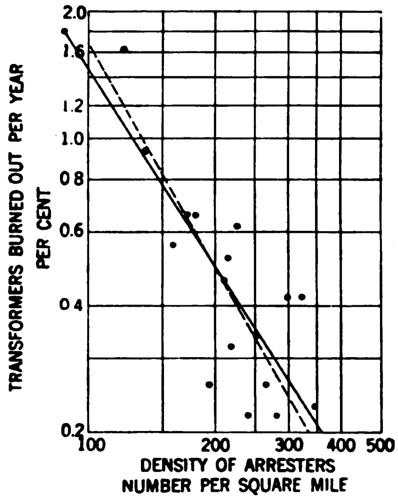

Fig. 13—Diagram to Logarithmic Scale Showing the Data in Table II and Fig. 11, Assembled into Eighteen Points Each Covering the Experience for the Five-Year Period With Approximately the Same Number of Transformers

formers represented by one point increases. The average curve represented by the dashed line in these four figures transferred to arithmetical coordinates is shown in Fig. 12.

While one engineer was engaged in the task of

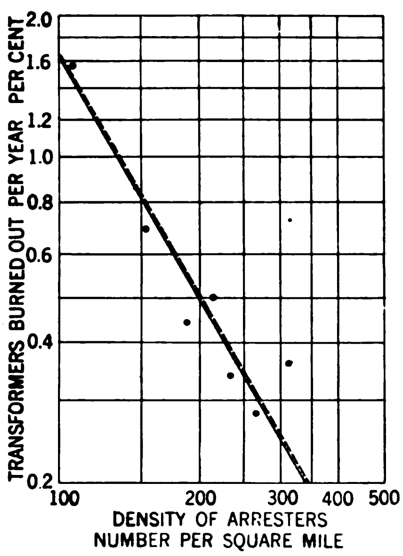

Fig. 14—Same as Fig. 12 Except That Data are Assembled Into Seven Points of Equal Weight

assembling the data and drawing the lines on logarithmic coordinate paper as above described, another engineer was given the task of assembling the data in a similar manner except that he used for each point the experience from an equal area covered by the lines as given in column seven of Table I, instead of an equal number of transformers. This was done with the idea that any serious personal errors or any error due to the assumptions made in drawing the curves or in transferring them to arithmetical coordinate paper would be indicated by differences in the final curves. After these two engineers had independently drawn final curves similar to the one shown in Fig. 12 the two curves were then transferred to the same sheet and found to be practically superposed. The equation of the curve in Fig. 12 is:

$$Y = \frac{5450}{X^{1.75}}$$

where X = the number of arresters per square mile, and
Y = The average per cent of transformers burnt out by lightning per year during the five-year period.

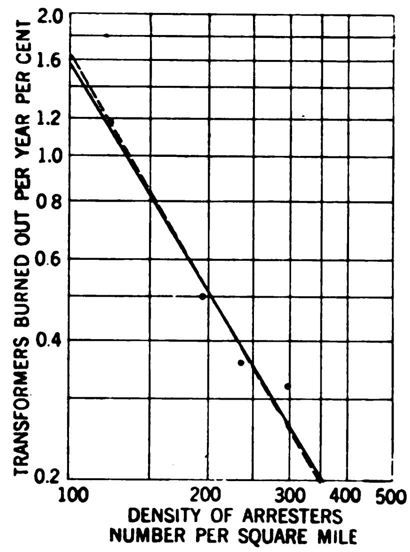

Fig. 15—Same as Fig. 13 Except That Data are Assembled Into Four Points of Equal Weight

This equation means that the density of arresters has a very important influence on the results secured by lightning arresters. If we assume for example, that there are 1000 transformers installed in an area of 10 square miles each protected by an arrester on the same pole, and that later the number of transformers in this area is doubled and at the same time uniformly distributed, the results of the change are shown in Table II. From this table it will be noted that although the number of transformers in the area has been doubled, the percentage of burn-outs has decreased from 1.67 per cent to 0.5 per cent and that the actual number of burn-outs has decreased from 17 to 10 per annum. In other words, the doubling of the number of transformers and arresters in a given area will not result in more transformers being burnt out by lightning per year as might be supposed, but will result in an actual reduction of about 40 per cent in the number of such burn-outs per year.

The data for each type of arrester were then plotted in a similar manner, a set of four curves similar to Figs. 13, 14, 15 and 16 being drawn for each type of arrester. As might be expected with a smaller number of observations, the variation of the points from a straight line when plotted on logarithmic paper and the variation of the four lines from their average was somewhat greater than in the case of the corresponding lines for all types of arresters. These straight

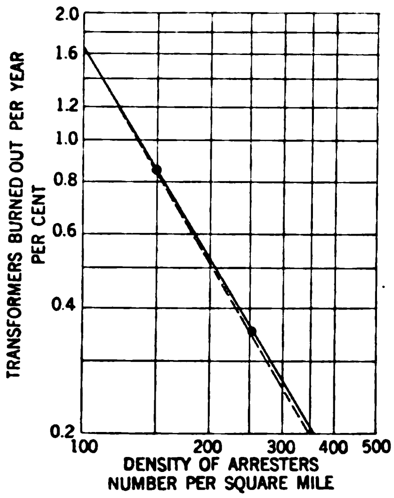

Fig. 16—Same as Fig. 14 Except That the Data are Assembled Into Two Points of Equal Weight

lines for the different types of arresters were not parallel, and when transferred to arithmetical coordinate paper as shown in Fig. 17, the curves cross each other in a confusing manner. While the curves thus drawn may be mathematically accurate, they appear to be physically impossible as there seems to be no sufficient reason why one type of arrester should be better than another at one density and poorer at another density. It seems more reasonable

TABLE II

CALCULATIONS FROM ASSUMED DATA SHOWING THE EFFECT OF DOUBLING THE DENSITY OF ARRESTERS AND TRANSFORMERS

No. of arresters and transformers	Area square miles	Density of arrester	Average annual transformer burn-outs due to lightning	
			Per cent	No.
1000	10	100	1.67	17
2000	10	200	0.5	10

to suppose that if one arrester is better than another at any particular density of arresters, it will be better throughout the entire range of densities. After giving this subject considerable study it was decided to assume that the straight line representing the experience with any type of arrester, when plotted on logarithmic coordinate paper should be parallel to the line showing the results for all types of arresters, that is, the dashed line in Fig. 13. To make this change: the midpoint of the line for each arrester was found, which is a point so located that there are an equal number of arresters represented by the line on either

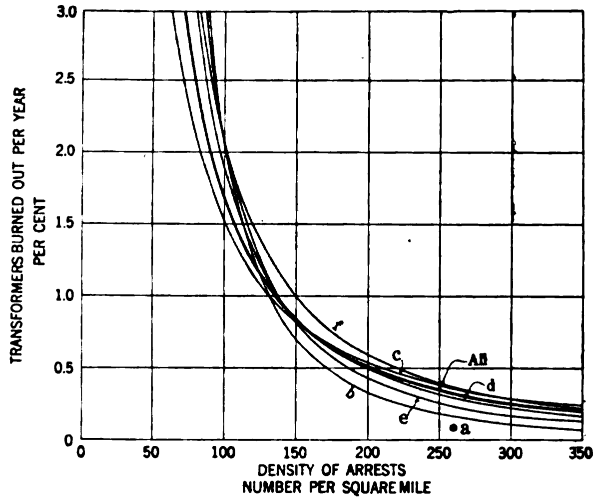

Fig. 17—Diagram Showing the First Approximation of the Relation Bweteen the Density of Arresters and the Percentage of Transformers Burned Out by Lightning for the Five-Year Period, 1915-1919 Inclusive

The curve for all arresters is plotted from the dashed line in Figs. 13 to 16 inclusive. The curves for the individual types of arresters were derived in a similar manner from logarithmic diagrams which are not reproduced.

A point instead of a line is shown for arrester *A* as the records for this type include only one transformer burn-out in the three years in which the arresters have been in service.

side of the point. The line which was finally taken as representing the experience with this type of arrester was then drawn through this midpoint and parallel

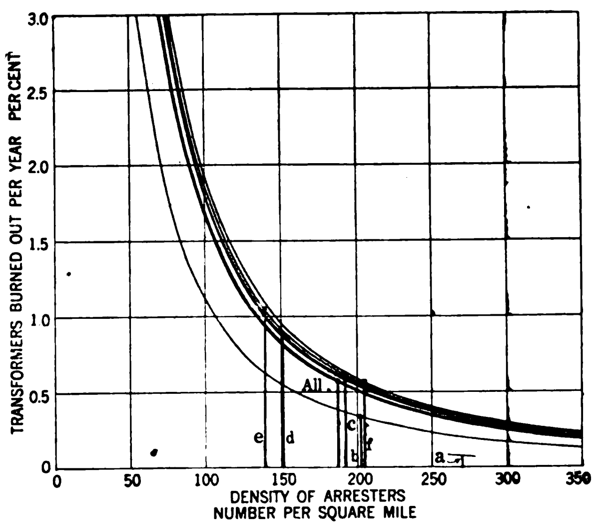

Fig. 18—Diagram Showing the Final Determination of the Relation Between the Density of Arresters and the Percentage of Transformers Burned Out by Lightning

These are the curves shown in Fig. 17 modified by the assumption that the lines representing the data on logarithmic paper should be parallel to the dashed line in Figs. 13 to 16 inclusive, showing the experience with all types of arrester.

to the dashed line in Fig. 13. The results of this assumption when transferred to arithmetical coordinate paper are shown in Fig. 18. If these several

assumptions are reasonably accurate, and they appear to do no violence to the facts, then the methods which have been used result in curves which can be taken as representing the performance of each of the arresters with varying densities, and the most troublesome variable, that is, the variation in the distribution and intensity of the lightning has been eliminated by the method of assembling the data and drawing the curves. From these curves it will be noted that four

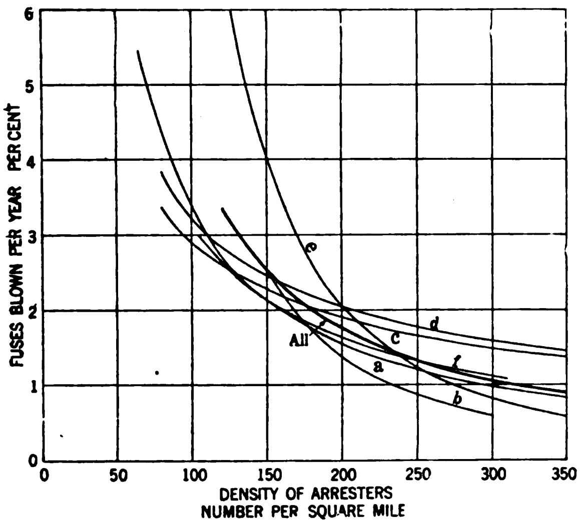

Fig. 19—Diagram Showing the First Approximation of the Relation Between the Density of Arresters and the Percentage of Transformer Primary Fuses Blown by Lightning, Plotted in the Same Manner as the Curves in Fig. 17

The curve for arrester *A* in this and the following figure was secured by using the records by quarter sections so as to secure an increased number of points.

of the arresters designated as *C*, *D*, *E* and *F* are so close together that the differences may be considered as well within the possible errors of observation.

In Fig. 18 an ordinate has been drawn to the mid-point of each of the curves as above defined or at the position corresponding to the average density for that curve, that is, for each type of arrester the number of arresters to the right of the ordinate is the same as the number to the left. These ordinates represent the same values that were given in the previous paper as showing the average experience for each type of arrester, but it is now seen that in the case of the four arresters *C*, *D*, *E* and *F*, the curves are so close together that the ordinates for these curves, instead of correctly representing the relative merits of the four arresters, are practically four different ordinates of the same curve. The four arresters are therefore of practically equal protective value.

It will be noted that the ordinates for curve *B* in Fig. 18 are about 40 per cent of the corresponding ordinates of the average of curves *C*, *D*, *E* and *F*. Arrester *B* is one of the oldest types on the lines and the arresters are fairly well distributed over a wide range of density as shown in Fig. 10. It is, therefore, considered that this difference of about 40 per cent as compared with the other four is a real difference due to the value of the arrester as a protective device and is not due to an error in the observations or calculations.

In the case of arrester *A*, Fig. 6 shows that this arrester was installed in only three contiguous sections and Fig. 10 shows that these sections had a narrow range in arrester density. In addition the arresters had been in our service for only three years and in view of all of these circumstances, it appears that the data regarding this particular type of arrester are not conclusive. For the purpose of securing more conclusive data regarding this type of arrester, additional arresters were installed early in 1920 in the areas shown by the heavy shading in Fig. 6. The light shading in the same figure shows the areas in which an additional type of arrester was installed early in 1920.

The data showing the relation between density of arresters and the per cent of primary fuses blown by lightning were treated in the same manner as the data for the transformer burn-outs, and the results are shown in Figs. 19 and 20. On account of the fuse trouble experienced in 1918 and 1919 as mentioned earlier

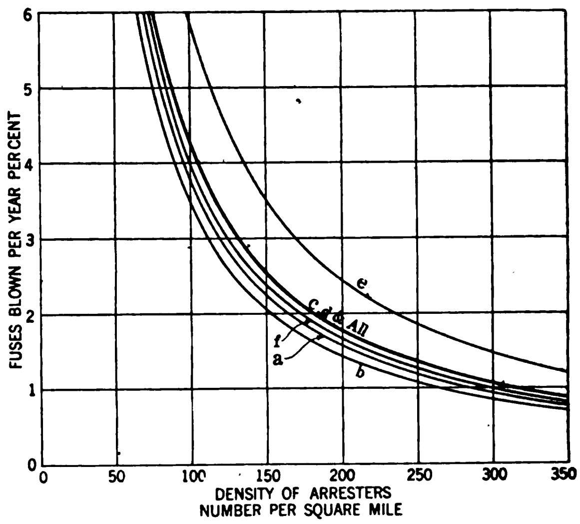

Fig. 20—Diagram Showing the Final Determination Between the Relation of the Density of Arresters and the Percentage of Transformer Primary Fuses Blown by Lightning During the Five-Year Period 1915-1919 Inclusive

Plotted in the same manner as the curves in Fig. 18.

in the paper, the percentage of fuses blown which have been ascribed to lightning in the two years is known to be higher than the actual figure. This trouble was eliminated by the change of all the fuses to a new type during the latter months of 1919 and the earlier months of 1920. The marked reduction in the percentage of fuses blown by lightning in 1920 indicates that this particular form of fuse trouble has been eliminated. The principal cause of the blowing of transformer primary fuses in lightning storms is due to the arcing

across the bushings where the primary wires enter the transformer case, and the scars from these arcs can generally be located. Some of the transformer manufacturers have increased the size of these bushings in their later designs and our records indicate a considerable reduction in the amount of trouble from this cause with the enlarged bushings.

On account of the nature of this trouble and on account of the several factors which modify the results, it is thought that the curves in Fig. 20 are less accurate than the corresponding curves for transformer burnouts as shown in Fig. 18. The curves are, however, of the same general shape and show that there is a marked decrease in the percentage of fuses blown to the increase in density. The equation of the curve for all arresters in Fig. 20 is

$$Z = \frac{1300}{X^{1.75}}$$

where X = the number of arresters per square mile

and Z = the per cent of fuses burnt out due to lightning.

The investigation discloses a remarkable decrease in the percentage of transformer troubles caused by lightning with the increase in the number of arresters per square mile. The curves show further that there is a rather high percentage of troubles for the very low densities, and in those systems where the transformers, each of which is protected by an arrester on the same pole, are located several blocks apart, it is possible that although the arresters are actually of considerable benefit, the percentage of troubles is still so high that there may be some doubt in the minds of those in charge of such systems as to the value or even the advisability of installing lightning arresters. Where such conditions exist, the installation of additional arresters would in all probability reduce the percentage of trouble caused by lightning to such an extent that their installation would be entirely warranted by a reduction in operating expenses.

5. Lightning Arresters on Cable Poles

As indicated in the description of the system, about 25 per cent of the primary feeders and mains are underground, and there are about 2500 cable poles where the underground feeders or mains are connected to the overhead wires. At all of these cable poles each of the cables is protected by an arrester installed on the cable pole in a manner similar to those installed on transformer poles. These arresters have not been included in figuring the density of arresters for the protection of transformers.

It is a matter of common knowledge in Chicago that some years ago when the number of substations supplying the system was only one-fifth of the present number and when the average distance between transformers was considerably greater than at present, that there was a large percentage of cable troubles due to lightning. This was particularly true where a short length of underground cable required for the crossing of a boulevard or a branch of the Chicago River or by other local conditions was of necessity inserted in a long stretch of overhead line. The records also show that although the load has increased more than tenfold since that time and the number of cable poles has probably increased in an even greater ratio, the annual number of burn-outs of such cables due to lightning has not increased and has probably been reduced. In 1918, for example, when the amount of damage to transformers by lightning was about the average for the five-year period as shown by Fig. 4, there were only three burn-outs of cables due to lightning, all of which occurred either at or in the vicinity of the cable poles. This number was about 1/15 of 1 per cent of the total number in service. This information, together with the curve in Fig. 18, leads to the conclusion that the arresters which have been installed on our lines for the protection of transformers must also assist in the protection of cables connected to the overhead lines. It also appears to be equally true that the arresters installed on the cable poles must assist in the protection of the neighboring transformers. These cable poles are fairly well scattered over the entire system and an examination of the maps and a count of the arresters on cable poles in a few sections indicates that the arresters on cable poles bear a fairly constant ratio to the arresters on transformer poles. If these arresters on the cable poles were included in calculating the density of arresters in Table I and in Figs. 17, 18, 19 and 20, it would probably be found that the curves in these figures would be slightly altered in their position without materially altering their form. The omission of the lightning arresters on cable poles in connection with Table I and the curves which follow does not appear to be a serious error as the exact values of the percentage of burn-outs or of fuses blown for any given density refer specifically to Chicago conditions, while the form of the curves probably represents a fundamental principle in lightning protection.

If the density of the arresters in the vicinity of a cable pole is an important feature of lightning protection for cables connected to 4000-volt lines, it should be equally important in connection with arresters for the protection of cables connected to higher voltage lines. In and near many of the larger cities it is a quite common practise to have a number of lines partly overhead and partly underground operating at voltages from about 6000 to 25,000. There is a wide difference in the practise of various companies in the protection of such cables from lightning; some companies claim that so little benefit has been received from the installation of lightning arresters on their 13,000 or 25,000-volt cable poles that they are no longer installed; other companies consider that the

probability of interruption due to lightning is so great that they do not connect overhead lines to underground cables except in substation buildings where there are also installed transformers for changing the voltage, together with the usual equipment of arresters for the protection of the transformers. The transformers installed in this manner serve to isolate the overhead line from the underground cable and thus effectively protect the cable from lightning.

In such cases where lightning arresters are installed at points where high-voltage cables are connected to overhead lines, no company installs more than a single arrester. In Chicago there are a number of such cable poles on 12,000 and on 20,000-volt cables, and the percentage of burn-outs of these cables due to lightning is of the order of 10 per cent per annum, while in the 4000-volt cables it is a small fraction of 1 per cent. In view of this experience and of the curve showing the effect of density of arresters on the efficiency of the protection of line transformers, it appears that the high percentage of burn-outs experienced with the high-voltage cables is largely due to the low density of arresters in the immediate vicinity of the cable pole, and that a very considerable reduction in the percentage of such burn-outs could be secured by the installation of additional arresters in the vicinity of the cable pole.

6. Comments on the Designs of Lightning Arresters Covered by this Investigation

The earlier types of lightning arresters were all made with the metal parts enclosed in a wooden case so that the arresters could be periodically inspected, adjusted and repaired. The arcing parts were so designed that they could be readily renewed. The practise was to make an annual inspection followed by the necessary adjustment, repairs and replacements, and this annual overhauling was a serious item of expense.

Early in the period covered by these investigations, one of the manufacturers brought out a type of arrester which was self-contained, that is, the metal and other current-carrying portions of the arrester were assembled in a porcelain casing which did not require an external wooden box for its protection. In this type of arrester the metal parts and resistance rod are assembled in a porcelain housing, the several parts being fastened together by means of a sealing compound so that it is not feasible to inspect or repair these arresters while they are in position on the poles. The gaps in this new type, instead of being between brass points or spheres, are between round parallel plates so that a number of successive heavy discharges will not seriously alter the total length of the gaps. After several years' experience with this type of arrester, the conclusion was reached that such arresters had many advantages over the wooden box type besides a considerably reduced annual maintenance charge and it appeared entirely possible to make such arresters so that they would have a protective value equal to the earlier wooden box type. On reaching this decision the manufacturers were advised that no further purchases would be made of arresters which required a wooden box for their protection. Several types of arresters have been produced by the manufacturers since that time and several modifications in the design of the arresters have been made as a result of the information from these investigations which were communicated to the manufacturers from time to time. It is possible that the experience with the several types of arresters covered by these investigations, as well as the earlier types which they replaced, may be best summarized in the form of a tentative specification for lightning arresters, which would state some of the important points to be included and to be avoided in such design. Such a specification would read about as follows:

1. The arrester must consist of a number of gaps in series with a resistance, with the number of gaps and the amount of resistance properly adjusted to the line voltage so that the dynamic arc following a lightning discharge will be quickly broken without damage to the arrester.

2. The resistance rod must have the resistance uniformly distributed throughout its length, so as to prevent the progressive short-circuiting of the rod with heavy lightning discharges and the destruction of the arrester which will follow.

3. The amount of resistance in the resistance rod should not be seriously affected by repeated heavy discharges.

4. The leads for connecting the arrester to the line should leave the arrester so that they will form drip loops, and the leads should be so arranged that the arrester can be connected to a line wire on either side of the arrester.

For low maintenance cost the following features are desirable:

5. The enclosing case should be of fireproof insulating material that is not affected by the weather; and it should be constructed so as to protect effectually the metal parts from the weather, and to prevent accumulation of dust on the gaps.

6. The gaps in the arrester should be between parallel plates, disks, or rings instead of between cylinders or spheres so as to permit repeated heavy discharges without seriously altering the length of the gaps.

7. The arrester should be constructed so that in the event of the failure of the arrester to interrupt the dynamic arc the enclosing case will be shattered by the heat so as to give some visual evidence of the trouble and result in the opening of the circuit.

8. The arrester should be without moving parts or parts which require inspection, renewal or adjustment and should preferably be made in the form which

cannot be inspected or repaired without removing it from the pole.

The experience with the arresters covered by this investigation indicates that several types of arresters are now available which comply with all of these specifications. The annual maintenance cost has up to the present time averaged well below 1 per cent per annum and is practically confined to the replacing of damaged arresters. It is possible that the present forms of gaps will not permit of an indefinite number of discharges without affecting the protective value of the arresters, but if such a condition should arise it would probably be manifested by an increase in the percentage of transformers burned out by lightning. The condition of the gaps could be determined by emoving from the line and examining and testing the arresters which were protecting transformers that had burned out. The maximum number of arresters to be treated in this manner would be less than 1 per cent of the total number installed and this number in all probability could be considerably reduced by careful investigation of the conditions surrounding their installation along the lines described in the earlier part of this paper, and this would serve to still further reduce the cost.

7. Suggested Future Plans

In Chicago it is the standard practise when making line extensions to install in the center of each block one pole larger and stronger than the others for a future transformer pole. By going over the map of the distribution system it has been found that if additional arresters were installed on these future transformer poles, so that each transformer will be protected not only by an arrester on the same pole but also by additional arresters one block away in each direction along the lines, then the additional arresters required will only be 2 per cent of the total number at present installed for the protection of transformers. Calculations made with the aid of the curves show that these 2 per cent additional arresters will result in a saving of at least 7 per cent of the present number of burn-outs. The installation of these additional arresters would, therefore, appear to be warranted by the reduction in the operating and maintenance charges.

There appears to be a number of locations where submarine cables crossing the river, or lead-covered cables at other locations, connect with the overhead lines at points which are several blocks removed from the nearest transformer and they are, therefore, protected only by an arrester on the cable pole. In such cases it appears that additional arresters would be warranted in the vicinity of such cable terminals, and particularly so in the case of submarine cables and perhaps other special cases where the cost of repairs would be very heavy. In some cases where an overhead line is supplied from a single underground cable, and where there are no arresters on transformers within several blocks of the cable pole, it may be possible by the installation of additional arresters in the vicinity of the cable pole, to save the cost of an emergency supply.

8. Differences between Laboratory Tests and Service Experience

The investigation and the calculations herein described indicate that four types of arresters differing in such details of design as the number of gaps between line and ground, the amount of series resistance, and other features, are so nearly alike that they can be considered as having identical protective value under the conditions of service. The results of the laboratory tests, however, indicate that the arresters are quite appreciably different in their protective value, and up to the present time it has been found impossible to reconcile the results of the laboratory tests with the experience in service. It is suggested, however, that the impedance of the ground wire and of the pipe used as the lightning arrester ground may be sufficiently high to overshadow the differences in the amount of resistance and the number of gaps, and in this way tend to equalize the behavior of different types of arresters under the conditions of service. In view of these differences and of the expense and the time required to determine the relative merits of different types of arresters from the experience in service, it is suggested that it would be very interesting and valuable development in the art if some form of laboratory tests for lightning arresters could be devised whose results would more nearly agree with the results of experience in actual service.

9. Conclusions

The conclusions from the investigations described in this paper, together with the more important conclusions from the previous paper, some of which have been modified and extended by these investigations, may be summarized as follows:

1. Transformer troubles during lightning storms may be reduced (a) by the removal of transformer primary terminal boards, (b) by the installation of lightning arresters, (c) by the use of larger bushings on the primary leads of transformers where they enter the case.

2. Lightning arresters installed on transformer poles are considerably more effective than if installed on the line poles.

3. Even in the most severe lightning storms, which apparently cover the given territory quite completely, there will be numerous extended areas within this territory which will be entirely free from lightning disturbances. Careful records extending over a period of several years are, therefore, necessary in order to determine definitely whether immunity from troubles due to lightning is due to the efficiency of the lightning protection or to the absence of lightning.

4. There is a very marked improvement in the effect of lightning arrester protection with an increase in density, that is, the number per square mile, and this effect is such an important factor in their performance that no accurate comparison of the relative merits of various types of arresters can be made without giving this point proper consideration.

5. Where the number of transformers, each of which is protected by an arrester on the same pole, is large per square mile so that the transformers and arresters are on the average only a few hundred feet apart, the total combined effect of all of the adjacent arresters is greater than that of the arrester on the same pole with the transformer.

6. In districts where transformers are widely scattered, that is, where the local density is materially below 100 per square mile and where continuous service is important, it will probably be found desirable to install arresters on line poles in addition to an arrester on the same pole with each transformer; where the local density is of the order of 50 per square mile, or lower, the installation of such additional arresters will probably be found to be warranted solely by the reduction in operating expenses.

7. The increase in the density of lightning arresters also results in a marked decrease in the percentage of burn-outs due to lightning of underground cables connected to overhead distribution circuits, and while the exact figures for the early years are not available, the percentage has been reduced from several per cent per annum with a very low density to a figure running well below one-tenth of one per cent per annum with the density averaging about 200 per square mile.

8. In the case of high-voltage cables, that is cables operating at voltages ranging up to 25,000, and where the present practise in this country calls for a maximum of one arrester at the point where the underground cable connects with the overhead line, the installation of additional arresters in the vicinity of the cable pole would in all probability cause a marked reduction in the percentage of burn-outs of such cables due to lightning.

9. The effect of density of arresters, of the shielding effect of high buildings, trees, etc., and perhaps also other features, have such an important effect on the amount of trouble from lightning that no accurate comparisons of the results secured in different cities can be made without giving due consideration to all such features of the conditions under which the lightning arresters are installed.

10. For use in the protection of transformers in districts where each transformer is protected by an arrester on the same pole and where the density of arresters ranges above 200 per square mile, the most economical arrester of the several types covered by this investigation is probably the cheapest arrester. It is entirely possible and even probable that the local conditions will have an important bearing in determining the best type of arrester to be used in any given locality, and that where the amount of shielding from buildings, trees, wires of other companies, etc., is very slight and where the securing of adequate ground connections for the arresters is expensive it would be preferable, even in areas of low density, to use arresters whose discharge capacity is considerably greater and whose discharge potential is considerably lower than the arresters covered by these investigations and to confine the installation of the arresters to the transformer poles.

11. It is possible, by carefully distributing the various types of lightning arresters over a large area and by securing the results of the performance of arresters over a period of years, to place the several types of lightning arresters used for the protection of transformers under conditions that are practically identical as regards the features which would affect the relative performance of the various types of lightning arresters, and to secure data which will permit a comparison of the relative merits of the several types of lightning arresters as protective devices.

12. It is entirely possible to make lightning arresters of the self-contained type, that is, of a type not requiring an external protecting box and so constructed as not to require or permit inspection. The annual maintenance cost of such arresters is practically limited to the replacing of damaged arresters, and the total annual maintenance cost as indicated by an experience of five years with several thousand such arresters is well below 1 per cent of their original cost of installation. The adoption of such types of arresters will result in a material reduction in the annual maintenance cost as compared with the older types.

13. A change in the form of lightning arrester gap from a cylindrical or spherical shape to parallel flat surfaces which was adopted by the manufacturers when changing from the wooden box type to the self-contained type of arrester, appears to result in a form of design which allows repeated heavy discharges without requiring renewal or adjustment of the parts, and has been an important factor in changing the design from a type requiring annual inspection, renewal and adjustment to a type which does not permit or require such annual attention.

14. The four types of arresters which have been designated by the letters *C*, *D*, *E* and *F* and which consist essentially of a resistance in series with a number of gaps, together with such additional features as antennas, compression chambers, expulsion chambers, and solenoids to vary the length of the gap following dynamic discharge, all appear to be practically identical in their value as devices to protect line transformers.

15. The type of arrester designated by *B*, which consists of a large number of gaps in series without any resistance, in addition to two other paths through a high and a low resistance shunting a large and a small

number of gaps, appears to be considerably better protective device than arresters designated by C, D, E and F, and as far as can be determined from present information, this difference in its value as protective device appears to be due to features of its design.

16. With the aid of the data contained in this paper it should be possible to make estimates of the cost and results of lightning protection in Chicago with the same degree of accuracy as the estimates of cost of construction or maintenance of overhead lines, when the figures are averaged over a period of years.

17. The shielding effect of high buildings, trees and other similar features which might be considered as determining the exposure of the lines to lightning have an important bearing on the amount of damage that will be caused by lightning. In local areas in a distribution system which have for years shown a high percentage of troubles caused by lightning and where the troubles have been allowed to persist because of the thought that some mysterious influence local to the neighborhood attracted the lightning, it will probably be found that a large percentage of troubles is due to the lack of shielding from the surroundings or a low density of arresters, and that the trouble can be materially reduced by increasing the density of the arresters in the locality.

18. Great caution should be used in attempting to compare the results secured by lightning arrester protection in Chicago with results secured in other localities without giving due consideration to all of the factors which might affect lightning arrester performance.

In conclusion the author desires to express his appreciation to the General Electric Company and the Electric Service Supplies Company for their many helpful suggestions and hearty cooperation during the progress of the investigations.

ENGINEERING COURSES FOR EX-SERVICE MEN

Under the law passed by the last session of Congress, the Federal Board of Vocational Education has made arrangements to give electrical engineering courses at the expense of the Board to a total of 571 disabled ex-service men.

About 800 men are taking the mechanical engineering course and between one and two hundred men the mining engineering course. An effort has been made to choose schools and colleges in every section of the country so that they will be convenient and cover all the fields of engineering work.

There are at present 2387 men taking these engineering courses. Among the institutions being used by the Federal Board for this purpose are: Harvard University, Huntington School (Boston), Columbia University, Carnegie Institute of Technology, Lafayette College, Lehigh University, Pennsylvania State College, University of Pittsburgh, University of West Virginia, Georgia School of Technology, Michigan School of Mines, Rolla School of Mines, Montana School of Mines, South Dakota School of Mines, Colorado School of Mines, New Mexico School of Mines, University of Utah, Stanford University, University of Arizona, University of California, University of Nevada, University of Washington, El Paso School of Mines. These schools are distributed as follows: Nine schools in Massachusetts; five in New York City; five at other points in New York; twelve in Pennsylvania; six in Ohio; six in Illinois; three in Indiana; three in Tennessee; three in Michigan; three in Iowa; three in Kansas; three in Missouri; three in Colorado; ten in California; three in Oklahoma. In addition one or two schools in the following states have been designated: New Hampshire, Vermont, New Jersey, Connecticut, District of Columbia, Maryland, Virginia, Georgia, North Carolina, Alabama, Mississippi, Louisiana, Kentucky, Wisconsin, Nebraska, Minnesota, Montana, New Mexico, Utah, Arizona, Oregon, Washington, and Texas.

FOREIGN AVIATION INSTRUMENTS

Several new instruments, most of them of German manufacture, have been received from the Bureau's representative in Europe, and have been studied carefully with the object of obtaining information concerning the future design of aeronautic instruments in this country. A Bamberg distant compass (a German instrument) has been thoroughly investigated and some very interesting results have been obtained. This compass depends for its operation upon the characteristic of selenium which causes a variation in its electrical resistance with any change in the intensity of illumination falling upon it. The installation is so arranged that the compass itself may be mounted in the tail of the airplane at a distance from all disturbing magnetic influences. The bowl of the compass contains two electric bulbs diametrically opposed which throw their rays through a lens which concentrates them upon two corresponding selenium cells mounted on a bridge extending across the top of the bowl. A metal disk, corresponding to the card of the ordinary compass, is cut in such shape that it acts as a blind for the illuminating elements. Thus the intensity of lighting of the selenium cells is varied in accordance with the position of the magnetic element carrying this disk. By means of a properly arranged electric circuit, the position of the magnetic element is made known to the pilot by the indications of an ammeter suitably calibrated and mounted on the instrument board. The navigator is able to direct the pilot on a desired course by means of an indicator connected mechanically to the compass in such a manner as to make possible the rotation of the bowl at will by the navigator.

Electrostatic Condensers

BY V. E. GOODWIN

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In studying the progress of the electrical art one is continually confronted with the fundamental factors in Ohm's law—namely, volts, amperes, resistance, inductance and capacity. Of all these factors, the least practical use is made of the latter, and one is naturally interested to learn the reason for this apparent neglect when there are so many applications for this factor.

A review of the proceedings of the A. I. E. E. shows many references to the subject of electrostatic capacity or capacitance, but one finds only two papers on the subject of condensers, and one of these appeared over twenty years ago.

The purpose of this paper is to stimulate a more active interest in the development and application of electrostatic condensers. It is well-known that the electric condenser is one of the oldest electrical devices, and the thought naturally comes to mind as to why there has been so little progress made in its development during the past decade or two, during which there have been such rapid strides in other lines of the industry.

The author believes that a review of the subject at this time will tend to stimulate interest and promote a more rapid development in this branch of the art.

The first part of this paper will be confined to fundamental characteristics of condensers and their relations to electric circuits containing inductance and resistance, and includes a discussion of the effects of switching condensers on and off such circuits. The second part of the paper describes some of the more important applications of condensers and illustrates the great demand there is in the electrical industry for this class of apparatus.

SECTION I

An electrostatic condenser acts as a non-conductor or a very high resistance to a constant direct voltage and as a conductor while the voltage is varying. When voltage is applied and current flows, the condenser becomes a source of counter e. m. f. opposing the applied voltage, making the sum of the voltages in the circuit equal to zero. A condenser takes sufficient current so that its counter e. m. f. plus the counter e. m. f. of the series inductance and resistance is equal to the total applied voltage. Similarly, when a charged condenser discharges through a resistance and inductance, the applied voltage of the condenser is equal to the counter e. m. f. of the inductance and resistance. The characteristics of a condenser circuit are thus more or less dependent upon the characteristics of the series resistance and inductance. The above statements apply in general to all electrical insulation. Insulation is used to separate one conductor from another and therefore always forms part of a condenser.

Electrical energy can be stored in two forms, electrostatic and electromagnetic. In condensers energy is stored in the electrostatic form. In inductances energy is stored in the electromagnetic form. Electric energy in process of transfer from one point to another in an electric circuit always exist in both electrostatic and electromagnetic forms.

Both potential and current are necessary for the transmission of electrical energy. Thus, in the condenser, current must flow in order that electrostatic energy may be stored. Potential must exist across an inductance while the current and stored electromagnetic energy are increasing or decreasing. The rate (in watts or joules per sec.) at which energy is passing into or out of a condenser or inductance is equal to the product of volts times amperes.

A condenser stores energy while its voltage is increasing and gives out energy while its voltage is decreasing. An inductance stores energy while the current is increasing and gives out energy while the current is decreasing.

The fundamental equations for a condenser (using instantaneous values) are:

Quantity in coulombs $q = C\,e$ (farads $\times$ volts)

Current in amperes $i = C\,\dfrac{d\,e}{d\,t}$

Power in watts $p = e\,i$

Energy in joules or watt seconds $w = \dfrac{C\,e^2}{2}$

The fundamental equations for an inductance are:

Inductance in henrys $= L$

Potential in volts $e = L\,\dfrac{d\,i}{d\,t}$

Power in watts $p = e\,i$

Energy in joules or watt seconds $w = \dfrac{L\,i^2}{2}$

Oscillation Circuit. When a charged condenser discharges through an inductance the current at any instant is such that the inductance voltage is equal and opposite to the condenser voltage. The current starts at zero and can be zero only when the condenser is fully charged. The current is proportional to the rate of change of condenser voltage. The condenser voltage is equal and opposite to the inductance voltage. The inductance voltage is proportional to the rate of change of current. These conditions can only be met by a current varying according to a sine (or cosine)

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wave, the current lagging a quarter cycle behind the condenser voltage and leading a quarter ahead of the inductance voltage. The frequency of the sine wave oscillation is determined by the relations.

$$e = L\frac{di}{dt} = \frac{1}{C}\int i\,dt$$

where $i = I \sin 2\pi f t$

$$\therefore f = \frac{1}{2\pi\sqrt{LC}}$$

The energy then oscillates between the condenser and inductance, being all in the condenser when the current is zero and the voltage maximum, and all in the inductance when the current is maximum and the voltage zero. With the condenser initially charged to a given maximum voltage E, the maximum value of current during discharge is then determined by the relation:

$$1/2\, C E^2 = 1/2\, L C^2$$

$$\therefore I = \frac{A}{\sqrt{L/C}}$$

Such a circuit is called an oscillation circuit. Since there is no loss of energy (except that due to resistance, radiation etc.), it is possible to build up a large oscillation by the addition of a large number of small amounts of energy. For example, a voltage may be induced in the inductance while it is giving energy to the condenser. The building up of an oscillation by a number of large or small increments of energy received at the proper instants is called resonance.

If the oscillation circuit contains a small resistance the oscillation is damped or decreasing in amplitude. The condenser voltage is equal to the inductance voltage plus the resistance voltage. The conditions are then satisfied by a current wave which is the product of a sine curve by a hyperbolic curve.

That is $i = I\, e - \frac{Rc}{2L}$

$$t \sin \frac{1}{2\pi}\sqrt{\frac{1}{Lc} - \frac{R^2}{4L^2}}\quad t$$

This equation does not hold and becomes imaginary if R is equal to or greater than $\sqrt{\frac{4L}{c}}$

If R is equal to or greater than $\sqrt{\frac{4L}{c}}$ the total energy is dissipated in the resistance during one rise and fall of current and there is no oscillation.

If the circuit contains resistance and negligible inductance the current starts at a maximum and decreases to zero along a hyperbolic curve. $- i = I\, e^{-CRt}$

Condenser Connected to D-C. Circuit. When a condenser is switched onto a direct-current circuit containing a resistance R and a negligible amount of inductance, the current transient starts at a maximum and decreases to zero along a hyperbolic curve. If there is inductance in the circuit the current starts at zero and there must be at least one rise and fall of current. If the resistance is less than the critical value $\sqrt{\frac{4L}{c}}$, there will be a damped oscillation of current. If it were possible to have zero resistance, the oscillation would be continuous or undamped.

Condenser Connected to an A-C. Circuit. There are always more or less of current and voltage transients when the condenser is switched on. Any rise of condenser voltage above normal is due to series inductance. If the inductance is relatively small, the rise of voltage will be small as there will not be enough energy stored in the inductance to charge the condenser much above normal. If the inductance is relatively small, the current transient will be much larger (in per cent of normal) than the voltage transient. The energy of the transients is dissipated in the series resistance so that the current and voltage soon come to their normal values.

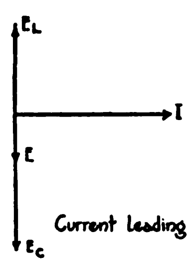


Fig. 1

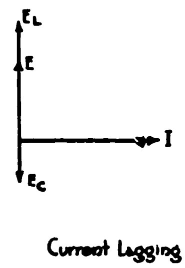


Fig. 2

The normal value of current is determined by the relation that the current is equal to the capacitance times the rate of change of voltage. The condenser current is proportional to and in phase with the rate of change of voltage. In the case of sine waves, the rate of change of voltage has the same wave shape as the voltage wave and a proportional maximum value, but passes through its maximum value a quarter cycle before the voltage wave. The rate of change of voltage at any instant is equal to $2\pi f$ times the voltage value which will exist a quarter cycle later. It is, therefore, permissible to say that the condenser current is proportional to the voltage but leads the voltage by a quarter cycle. This statement is true only for sine waves, but is generally used because commercial waves are approximately sine waves. It should be kept in mind that the fundamental fact is that condenser current at any instant is proportional to the rate of change of voltage at that instant. As usually stated, the current is proportional to and lags a quarter of a cycle behind the applied voltage.

When a condenser is in series with an inductance and the same sine-wave current passes through each, the inductance voltage is opposite in phase to the

condenser voltage and their difference is equal to the total applied voltage.

These relations are shown in the diagrams Figs. 1 and 2.

It is thus possible to raise the voltage and current of a condenser by a series inductance or to raise the voltage and current of an inductance by a series condenser. The current is leading if the condensive reactance is greater and lagging if the inductive reactance is greater. This depends upon the frequency as well as the capacitance and inductance. If the inductive reactance is equal to the condensive reactance the current is limited only by resistance and other losses. This is the condition of resonance. With a given capacitance and inductance, resonance can be obtained by varying the frequency. At a given frequency, resonance can be obtained by varying the capacitance or inductance. The condition for resonance is that $f = \dfrac{1}{2\pi\sqrt{LC}}$

When a condenser is connected in parallel with an inductance, the current and voltage relations are as shown in diagrams Figs. 3 and 4.

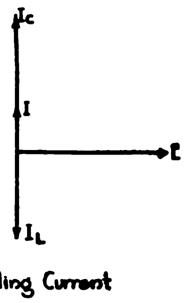


Fig. 3

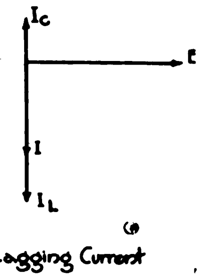


Fig. 4

As in the series connection, the line current may be made lagging or leading by varying the inductance, capacitance, or frequency. When the inductive reactance is equal to the condensive reactance, the current is purely a circulating current in the parallel connection and no current is taken from the line. It is thus possible to reduce the line current to an inductance by connecting a condenser in multiple and vice versa.

In the case of complex circuits containing capacitance, inductance, and resistance there are an unlimited number of possible combinations and each must be considered individually as met with. One such circuit which is of considerable theoretical interest is that of a condenser and inductance or equal reactance in series and a resistance in multiple with either inductance or condenser as shown in Fig. 5.

The vector diagram is given in Fig. 6.

From this diagram it is evident that the voltage applied to the condenser can be divided into two vectors, one of which is equal to and opposite the voltage applied to the inductance and resistance, and the other is in phase with I_L and equal to $X_C\, I_R$. This latter component is the total applied voltage E for any value of R. Similar relations hold when the resistance is connected in multiple with the condenser. $\therefore\ I_R = E/X =$ constant for any value of R. This circuit, therefore, gives a means of obtaining constant current from constant sine-wave voltage. There are a number of other more complicated circuits

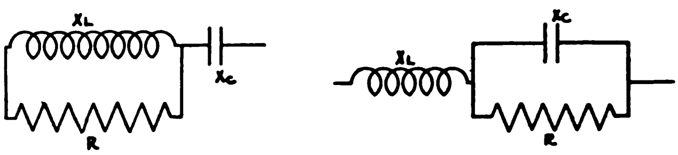


Fig. 5

giving the same results. These circuits have been known for many years but up to the present time have been considered only of theoretical interest. (For a complete treatment of these circuits, see Steinmetz' Theory and Calculation of Electrical Circuits.)

Distributed Capacitance. The foregoing discussion has referred only to a concentrated capacitance; that is, to a capacitance having a negligible inductance within itself. The usual forms of commercial condensers can for all practical purposes be regarded as concentrated. At low frequencies the capacitance of cables and transmission lines may be considered as made up of one or several concentrated capacitances. At high frequencies, transmission lines and cables must be treated as distributed capacitances and distributed inductances. High frequencies or high rates of change of voltage occur in the case of sudden changes of circuit conditions which set up traveling waves in transmission lines. It is principally in the phenomena and theory of traveling waves that the action of transmission lines as distributed capacitance and inductance becomes of importance.

Traveling waves are usually considered as having vertical wave fronts. This assumption is justified by the fact that it greatly simplifies calculations and because a vertical wave front is the limiting condition, and the effects calculated on that basis will mark the

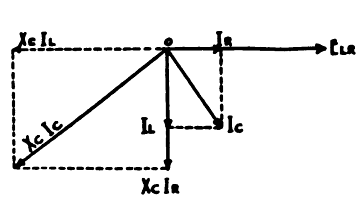


Fig. 6

maximum limit of any effects which could occur in practise.

One of the fundamental characteristics of a traveling wave is that the total energy is equally divided between electrostatic and electromagnetic energy. This fact is expressed by the equation

$$1/2\, C\, E^2 = 1/2\, L\, I^2$$

This equation follows directly from the fundamental equations:

$$Q = C E = I t.$$

$$\therefore \frac{C E^2}{2} = \frac{E I t}{2} = \frac{1}{2}\text{ total energy.}$$

$$\therefore \frac{L I^2}{2} = \text{other } \frac{1}{2} \text{ “ “}$$

It also follows directly from the above equations that

$$E = I \sqrt{L/C} = I Z$$

where Z = the "surge impedance."

Another fundamental characteristic of an electric wave is that the voltage is doubled when striking a point of total reflection. At reflection the length of the wave is reduced by one half and the energy is all electrostatic. The electrostatic energy per unit of length is thus four times as great and the voltage twice as great as in the traveling wave.

When a traveling wave strikes a point of short circuit, the current doubles and the voltage reduces to zero during reflection.

SECTION II

The characteristics of condensers as outlined in Section I give them a wide field of application in electric circuits. In the following, an attempt will be made to discuss the more common and practical of these applications.

1. *Telephone Service.* In telephone circuits, it is often necessary to confine the flow of direct current to certain sections of a network of conductors and at the same time to allow alternating and pulsating currents to flow as desired. This separation is accomplished by means of condensers connected in series with the line at the limits of the d-c. zones. Thus it is possible to use alternating currents to call inactive stations and to separate the minute pulsating talking currents from the relatively heavy direct currents. The condenser in this service not only economizes in the amount of energy required, but also makes long distance telephony possible.

It is also interesting to mention the fact that specially constructed condensers can be used as telephone receivers. A condenser of this construction is known as the "singing" condenser as it will produce audible notes corresponding to the rates of change of the applied voltage impulses.

2. *Condensers in Oscillating Circuits.* The condenser finds a wide application in oscillating circuits where it is desired to produce high-frequency voltages or to study the effects of impulses having steep wave fronts.

Oscillating circuits are of two general types, known as the oscillation generator and the oscillation transformer. Fig. 7 shows the diagrammatic arrangement of the oscillation generator.

The purpose of this machine is to produce an impulse or train of oscillations of definite wave form whenever the alternator voltage is raised sufficiently to spark over the gap G. These machines have been of great value in studying the action of exceedingly high rates of change in potential and in the study and determination of the dielectric spark lag of insulating materials.

Fig. 8 shows circuit connections of the oscillation transformer.

The application of this form of apparatus is in the production of recurrent oscillation at high frequency and voltage. By varying the adjustable inductance L

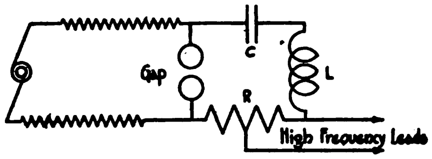


FIG. 7

and capacitance C, it is possible to obtain any desired frequency. By varying the ratio of the turns in the air transformer T, it is possible to obtain a wide variation in voltage of the high-frequency oscillation. This circuit is used extensively in wireless work, as will be described later, and in many forms of testing and laboratory work.

3. *Protection from Lightning and High-Frequency Disturbances.* The fact that a condenser stores energy as the voltage increases, and gives out energy as the voltage decreases, can be made use of in protecting electric circuits from abnormal disturbances having steep wave fronts. When a steep wave impulse reaches a point in the circuit where a suitable condenser is connected across the circuit, it delivers a steepness of wave form or rate of change of potential. The amount of energy

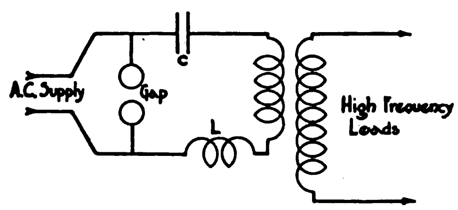


FIG. 8

delivered depends upon the voltage of the impulse and the capacitance of the condenser. This tends to make the wave front more sloping and less dangerous and also tends to lower its maximum potential in cases where the crest of the wave is short. When the impulse passes, its potential starts to decrease in what is known as the rear, or tail of the wave. The condenser then gives its energy back into the impulse, modifying the shape of the rear of the wave by making it likewise more sloping.

Another and more common, application of condensers for protection purposes is in the absorption and consequent elimination of high frequency. This applica-

tion is based upon the fact that the current flow in a condenser is proportional to the rate of change of potential and in the case of a recurrent oscillation to the frequency. The absorption is accomplished by inserting a resistance in series with the condenser. The value of resistance for maximum absorption with a given condenser is obtained when $R = \frac{1}{2\,\pi\,f\,C}$. The value of capacitance to be used should depend upon the nature and character of the oscillations which are to be handled by the machine. In actual practise these oscillations vary through a wide range in frequency and voltage. The actual designs of these machines employ a capacitance, for a given operating voltage, such as to allow a normal current from 0.05 to 0.10 ampere to flow at 60 cycles. Under normal conditions little energy is absorbed from the system. If, however, an abnormal recurrent disturbance is started by an arcing ground or other cause, the condenser, with its series resistance, acts like a valve operated by the frequency and allows more and more current to flow through the resistance as the frequency increases.

The impedance of a condenser with a series resistance is

$$Z = \sqrt{R^2 + \left(\frac{1}{2\,\pi\,f\,C}\right)^2}$$

Assuming R = 100 ohms, C = 0.01 microfarad
f = 60 cycles and E = 13,200 volts.
Then Z = 265,000 ohms.

At 13,200 volts the current at 60 cycles would be 0.05 ampere and the energy absorbed per second by

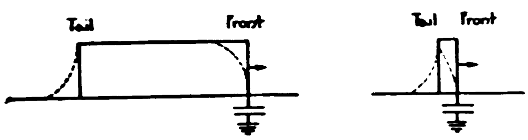


FIG. 9

the series resistance would be $0.05^2 \times 100 = 0.25$ watt-seconds.

If the frequency is 100,000 cycles,
Then Z = 188 ohms.

At 13,200 volts the current at 100,000 cycles would be 70.3 amperes and the energy absorbed per second $70.3^2 \times 100 = 494$ kilowatt-seconds.

From the above, it will be seen that at low frequencies the major part of the impedance is in the condenser while at 100,000 cycles the principal impedance is in the resistance R. The above calculations are based upon the resistance and capacitance remaining constant at all frequencies. This is not exactly true in practise as the capacitance of condensers and the conductance of resistance decreases as the frequency increases. This is due to the absorption factor of dielectrics and the skin effect and temperature coefficient of resistances. These are variable factors depending upon the shape and character of the materials used. With proper designs these factors should not have much effect at frequencies below 100,000 cycles.

Since many abnormal disturbances in electric circuits are of an oscillatory nature and have relatively little energy back of them, it would seem that an absorber of this character would prove an excellent protector, as its ability to absorb and consequently destroy oscillations increases so rapidly with the frequency and destructiveness of oscillations.

Another use of condensers as a protective device is in connection with what has been termed a resonant shunt. With this apparatus the condenser is connected in series with an inductance which is tuned to resonance for a given frequency. Oftentimes in electric circuits, it is found that there is present a certain harmonic or superimposed oscillation of a definite frequency which is detrimental to the operation of other apparatus at some point in the circuit. By connecting a resonant shunt across the circuit and having it tuned to the particular frequency of the undesirable harmonic will provide a short-circuit path which will entirely eliminate this undesirable part of the wave form and leave the fundamental wave unchanged. This combination should have a wide field of application particularly in eliminating such harmonics as are liable to produce telephone interferences.

A further application of condensers as a protective device would be to shunt series coils on regulators, current transformers, etc. These series coils being connected in the line will subject them to high rises of potential between turns whenever a traveling oscillation passes through them. By providing a shunt path consisting of condensers of such capacity as to allow little current to pass at normal frequency, it would be possible to shunt the major part of the high frequency disturbance through the condenser and thus prevent a rise of potential between turns and between the terminals of the series coil and thus relieve the strain on the insulation.

4. *Power Factor Correction and Improvement in Line Regulation.* Static condensers have a power factor of approximately 0.003 leading and an energy of loss of less than 0.5 per cent. For practical purposes, we can consider the power factor as zero leading as it is extremely difficult to measure even with the most sensitive galvanometers. In alternating current power service, it is therefore possible to apply static condensers to correct low power factors resulting from lagging currents.

Power factor corrections can be accomplished by either of two methods: First by retarding the voltage vector so that it becomes more nearly in phase with the current; and second, by advancing the current vector so that it becomes more nearly in phase with the voltage. The former scheme can be accomplished by the use of a

suitable condenser in series with the load, and the latter by means of a condenser in shunt with the load.

The problem of power factor correction has been quite fully discussed before the Institute in connection with synchronous condensers so it will be unnecessary at this time to point out the advantages accruing therefrom. The electrostatic condenser has, however, certain advantages over the synchronous type for certain classes of work and should find a wider application when their adaptability for this service is more fully understood. The following are some of the advantages of the electrostatic condenser for power work:

1. Being a stationary apparatus, no attention is required.
2. The high efficiency of the outfit means that the annual power loss is very small.
3. With reliable condensers the maintenance costs are practically nil.
4. The corrective kv-a. can easily be increased or decreased by simply cutting in or out of sections.

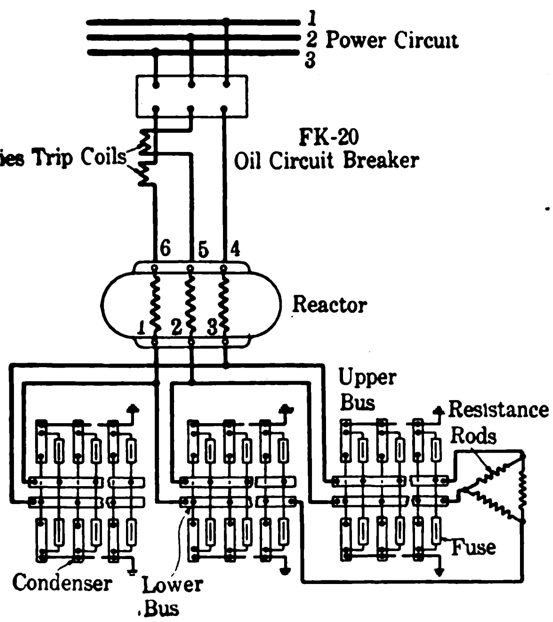
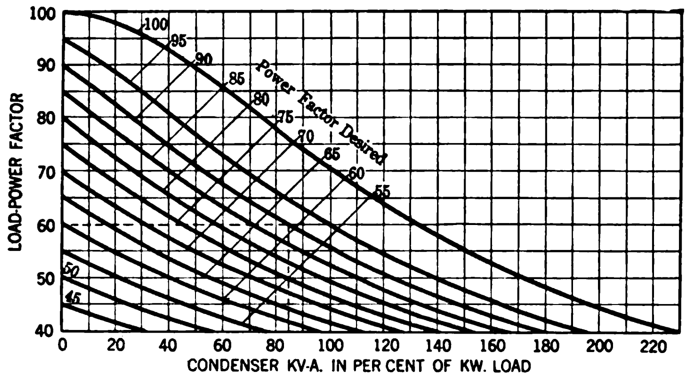


FIG. 10

5. The outfit can be connected to any part of the system and thus provide correction at the points where the greatest saving can result.
6. Noiseless and requires no special foundation.
7. Lower first cost for small installations.
8. It can also be used to improve the line regulation.

Fig 10 shows the diagrammatic connections of a static condenser used for power factor correction on a 2300-volt, three-phase circuit.

The condensers are connected in delta and each phase is divided into a number of sections each having a suitable enclosed fuse in series. A low reactance is connected in each phase between the circuit breaker and the condensers to act as a harmonic screen. This reactance can also be used to boost the voltage on the condensers so as to obtain greater corrective kv-a. with a given condenser. High resistances are connected in parallel with each phase of the condensers to discharge the condensers when they are disconnected from the line.



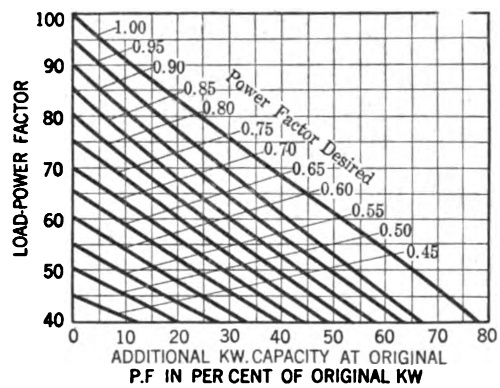
CURVE SHEET I—DETERMINATION OF CONDENSER CAPACITY REQUIRED FOR CORRECTING THE POWER FACTOR OF AN A-C. CIRCUIT

Follow horizontal line corresponding to present power factor of load until it intersects curve representing power factor desired. The vertical projection of this intersection on the base gives the size of condenser required in per cent of kw. load.

Example: Load 250 kw. Present power factor 60 per cent. Power factor desired 90 per cent.

Projection of intersection of 60 per cent power factor line with 90 per cent power factor curve gives desired condenser as 84.9 per cent of 250 kw. or 210 kv-a.

In studying the application of condensers for power factor work the author has found it more convenient to



CURVE SHEET II—DETERMINATION OF ADDITIONAL CAPACITY MADE AVAILABLE BY THE INSTALLATION OF STATIC CONDENSERS

Follow horizontal line corresponding to present power factor of load until it intersects curve representing power factor desired. The vertical projection of this intersection on the base gives the per cent of the original kw. load at the original power factor made available by the condenser.

Example: Load 250 kw Present power factor 60 per cent. Power factor desired 90 per cent.

Projection of intersection of 60 per cent factor line with 90 per cent power factor curve gives kw. load at 60 per cent power factor made available as 35 8 per cent of 250 kw. or 89.5 kw.

rate these units in terms of kv-a. at their rated voltage rather than in terms of capacitance.

If a sine wave of voltage E at a frequency f is impressed on a condenser section of capacity C farads, the current $I = 2 \pi f G E$

The leading kv-a. is $E I \times 10^{-3}$.

Hence, kv-a. $= 2 \pi f C E^2 \times 10^{-3}$.

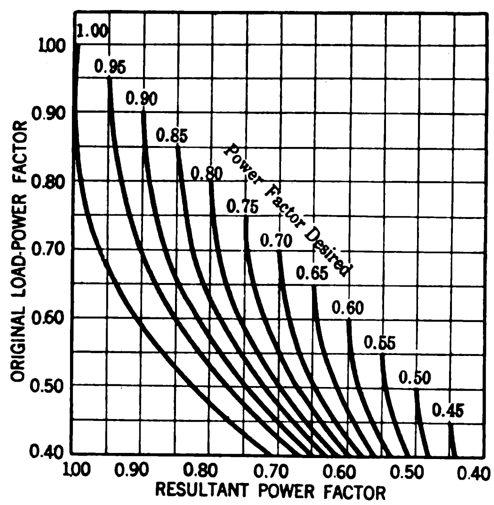
If C is expressed in terms of microfarads,

$$\text{kv-a.} = 2\,\pi\,f\,C\,E^2 \times 10^{-9}.$$

In the determination of the size of static condenser equipment required to correct the power factor of a given load, curve sheets I, II and III will prove of value. Curve sheet I gives the kv-a. correction required in percentage of the kw. load for any desired improvement in power factor from 40 per cent to 100 per cent.

In studying a problem of this character, the question naturally comes up as to how much additional load can be added at the original power factor after a certain correction has been added. These data are shown by curve sheet II.

Curve II indicates the amount of load at the original power factor that can be taken on a feeder, after correction has been added, without exceeding the initial heating in the lines and apparatus.



Curve Sheet III—Determination of Resultant Power Factor After Original Load at Corrected Power Factor has Been Increased by Additional Load at Original Power Factor so that the Total Kv-a. of the Circuit is Equal to the Original Kv-a.

Follow horizontal line corresponding to original power factor until it intersects curve corresponding to the corrected power factor. The projection of this intersection on the base gives the resultant power factor.

Example: A load of 250 kw. having a power factor of 60 per cent is raised to 90 per cent power factor by the installation of a static condenser.

A load of 89.5 kw. at 60 per cent power factor corresponding to the additional capacity made available by the correction in power factor is added so that the total kv-a. is equal to the original kv-a. The resultant power factor is obtained by projecting the intersection of the 60 per cent power factor line with the 90 per cent power factor curve upon the base and is found to be 81.5 per cent.

After the additional load indicated by Curve II has been taken on, it is desired to know the resulting power factor. These values are shown on curve sheet III. By the use of these three curve sheets, practically any information relative to loads and power factors can be quickly determined.

The static condenser is not necessarily a competitor of the synchronous condenser, since its principal application is in a field which has never been open to the latter machine.

During the past few years, there has been a gradual awakening throughout this country to the inefficiency of distribution networks resulting from low power factors. Operating companies, with a view to fairness to their customers, have added power factor clauses to their power contracts penalizing customers for low power factors. In other words, they aim to charge each customer for the delivery of his wattless or reactive load in addition to his energy load. This policy has opened up a new field for power factor correction which includes a large number of relatively small loads for which the stationary, or static condenser is particularly suited.

In the design of condenser sections the question of reliablity is of greatest importance. On the other hand, it is necessary to employ a dielectric of high permitivity. This dielectric must be very uniform throughout its entire volume. These conditions are very difficult to meet with very thin sheets even with modern insulations. It is therefore necessary to build up the dielectric of a condenser from several very thin sheets in order to obtain reliability. It has also been noted that as the number of sheets increased it becomes more difficult to radiate the heat. By studying these opposing factors for a given dielectric, we can arrive at a construction giving the most economic design. This gives a condenser which can be operated at any voltage up to its maximum reliable rating.

Since the kv-a. rating of a condenser increases as the square of the impressed voltage, operation at voltages less than normal results in reduced capacity. Hence, when considering a static condenser outfit for operating at voltages less than normal, it is often more economical to use a transformer to step up the voltage rather than to employ a greater number of condenser sections.

Another method of raising the voltage on a condenser is to install a suitable series reactance, but in doing so, care must be taken to avoid resonance.

5. *Electric Welding.* It is worthy of note in passing that reliable electric welding can be done with a circuit containing considerable capacitance. Preliminary work along this line indicates that equally good work can be done with circuits containing either inductance or capacitance, provided the power factor is of the correct low value. This low power factor is objectionable from the power supply standpoint. If, however, we divide our welding circuits into two groups, one using the condensive circuit and the other using the inductive circuit, it is possible to obtain unity power factor in the supply circuit.

Another application of the condenser to electric welding is based upon the fact that it is possible to charge a condenser slowly and to discharge it at a high ampere rate. This scheme is used quite extensively where small wires are to be welded together. By this means a definite amount of energy can be put into a welding and very uniform results obtained.

6. *Motor Application and Contact Sparking.* As previously shown, the phase relationship of current

to applied voltage depends upon the capacitance inductance and resistance in the receiving circuit. It is, therefore, possible with two or more receiving circuits to obtain two or more currents of different phase relationships from one supply circuit. This process is called phase splitting. These out-of-phase currents may be used to obtain starting torques or to change the running characteristics of single-phase motors. This method of starting gives better running efficiency than other methods for small single-phase motors such as fan motors, and there seem to be considerable possibilities for future developments in such uses for condensers.

A condenser may be used across the interrupter of an induction coil to eliminate sparking and consequent pitting of contacts and to increase the secondary voltages. The smaller the condenser, the greater the secondary voltage, provided there is no sparking at contacts. The smallest condenser which will eliminate sparking should be used. The formula for secondary voltage is

$$E_s = \frac{N_s}{N_p}\sqrt{\frac{L}{C}}\, I_b$$

where I_b = secondary current at break. In other cases condensers may be used merely to eliminate sparking.

7. *Laboratory Testing.* In the electrical testing laboratory, the uses for condensers may be divided into two general classes. The first class involves the condenser as a standard of capacity which may be either absolute, in which the capacity is capable of calculation from measurements of length, or comparison standard, which for convenience is used in the ordinary determination of the value of an unknown capacity. The usual comparison standard condensers employ either air or a very high grade of mica as dielectric. A well designed air condenser has the advantages of practically no absorption and the nearest approach to zero phase difference that can conveniently be obtained. It is, however, very bulky when a capacity of considerable magnitude is desired. The mica standard on the other hand, has an appreciable absorption and phase difference but can be constructed for capacities of several microfarads without becoming exceedingly bulky.

The second class of uses involves the condenser as an auxiliary piece of apparatus by the aid of which it is possible to obtain alternating currents of high frequency, to modify wave forms, and to duplicate and study in the laboratory many of the effects produced by atmospheric electric disturbances.

WESTERN ELECTRIC OFFERS NEW EDUCATIONAL ADVANTAGES TO ITS PERSONNEL

The opportunity to pursue part-time postgraduate studies at Columbia University is offered by the Western Electric Company to the members of its engineering department. Twelve employees will be selected to study for the degree of Master of Arts. These will be in addition to the other educational advantages which were started by the big telephone manufacturers at Columbia last fall.

Candidates for the new course must be employees who hold the degrees of Bachelor of Arts, Bachelor of Science, Bachelor of Philosophy, or an equivalent degree in engineering based on a four-year course of study in an institution whose academic standing is approved by the faculty of Columbia. The minimum academic preparation must include a year's course in calculus, a year's course in general physics and laboratory work, and a year's study in mechanics, optics, heat, electricity or equivalent engineering subjects.

The selection of the candidates will be based on evidences of their present attainments and the promise they have displayed in scientific work. Due regard will be given to the prospective ability of the candidate to employ further training to advantage in his duties with the Western Electric Company. Aspirants whose applications are not granted now may apply for future vacancies at Columbia.

The working hours in the offices and laboratories of the Western Electric Company will be adjusted to permit attendance at all the regular exercises of the university.

BRITISH RAILWAY ELECTRIFICATION

A Committee was appointed in March last by the Minister of Transport of Great Britain to advise what regulations are necessary to ensure that the future electrification of the railways in this country is carried out to the best advantage, more particularly as regards uniformity of equipment. The committee has issued an interim report which recommends that regulations should be issued in accordance with the following conditions:

1. That in the case of those railways which have not as yet electrified any lines, as well as those which at present have electrified all or part of their lines on a direct-current system, their electrification, or extended electrification, as the case may be, should be carried out on the direct-current system.

2. That the standard pressure of the direct-current system at the substation busbars shall be 1500 volts, subject to (*a*) the continuance of any existing 600-volt or 1200-volt installations, and subject to the approval of the Minister of their extension. (*b*) The adoption of half the standard voltage—750 volts—in those cases where it can be shown to the satisfaction of the Minister that advantage would arise from the use of this lower pressure. (*c*) The adoption of higher pressures—limited to a multiple of the standard pressure—where it can be shown to the satisfaction of the Minister that sufficient advantage would accrue.

3. That both overhead and rail conductor collection should be permitted, as long as the position and general design of the conductors and structures are

in accordance with recommendations which will be made in a subsequent report.

4. That the generation of current for direct-current lines should be alternating three-phase at such voltage as may be desirable in each case.

5. That in the case of existing generating stations supplying at any frequency between 25 and 50 cycles, it is unnecessary to make any change in frequency, but that it is desirable that where any one such frequency is in general use in a particular electricity district, any new power station put down in that district for supplying a railway should adopt the frequency which has been approved by the Electricity Commissioners or is in general use in that district.

Commenting on the subject of railway electrifications in Great Britain, *The Engineer*, London, says:

"Because of the lack of definite conclusions, railway electrification in this country has drifted into a somewhat unsatisfactory state. There are direct-current lines working at various voltages and single-phase lines. There are also three-phase alternating plants working at various periodicities. The introduction of a standard periodicity for all the electric railways would involve scrapping much converting plant. Assuming, for example, that the low-pressure direct-current railways are still to be worked at 600 volts, but that the supply periodicity is to be raised to 50 cycles in all cases, then new rotary converters would be needed on all the railways and tramways at present worked with 25-cycle current. There is nevertheless much to be said for the standardization of 50-cycle three-phase generators, and there is no real objection to the new super-power stations containing such machines, provided the railway companies are permitted to generate or obtain from existing stations the most suitable current for working their trains. A periodicity of 16 cycles per second is the best for single-phase traction, but 25-cycle current also gives good results. Many 25-cycle stations already in operation might be used for working single-phase lines. It remains to be shown whether any particular electrification system is good for all railways. When the matter is thoroughly investigated it may easily be found that although the so-called high-tension direct-current system would in many cases give excellent results, in other instances the alternating system would be very much better. Standardization is no doubt in many ways a good thing, but it is difficult to see how it can now be applied profitably to British railway electrification."

AIRCRAFT STANDARDIZATION

Acting upon a request from the Secretary of the International Aircraft Standards Commission, that arrangements be made, if possible, for American participation in the next meeting of the Commission, the American Engineering Standards Committee invited the various government and industrial organizations interested in aircraft standardization, to send representatives to a conference to discuss the question. The conference, which was held in Washington on August 11th, was attended by representatives of the Departments of War, Navy, Post Office, Commerce, and Agriculture, the National Advisory Committee for Aeronautics, the Society of Automotive Engineers, Manufacturers Aircraft Association, American Society of Mechanical Engineers and the American Society for Testing Materials.

It was the unanimous view of the conference that there should be American participation. A committee was appointed to present the matter to the President through the Chairman of the Council of National Defense. As a result, the President addressed a letter to the National Advisory Committee for Aeronautics requesting it to arrange for the presence of American representatives at the conference. The National Advisory Committee for Aeronautics is taking steps to provide such representation.

THE CHAMBERLAIN ROAD BILL

Interested organizations, especially the American Association of State Highway Officials, are now showing active interest in the Chamberlain bill, which it will be recalled proposed an appropriation of $400,000,000 for the continuation of Federal aid to the rural post roads program. This appropriation according to the terms of the bill is to be made available for construction work at the beginning of the fiscal year June 30, 1922. $100,000,000 is available during each of the four years subsequent to this date.

The Chamberlain bill provided that special attention and preference is to be given to the projects that will expedite the completion of an extensive National highway system which is to be inter-connecting at the state boundaries.

In general, the Chamberlain bill carries the provision under which the present Federal aid road act is operating. The Chamberlain bill also proposes to make provision for the public land states as follows: "In each state in which the precentage of total land area to which the title of the United States is unqualified, exceeds ten per cent of the total area of all lands in the State, the Secretary of Agriculture may reduce the ratio of co-operation required, but not to below one-half that which the total of the patented land and national forest land bears to the total area of all lands in the state." A separate fund is also provided for the National Forest roads and trails.

The advisory highway board appointed by the Secretary of Agriculture, a part of the membership of which is composed of state highway officers, has had a number of informal meetings in Washington for general discussion of highway problems. It is understood that they have been considering the terms and merits of the Chamberlain bill.

The Relation of Radiant Energy to Matter, Space and Time*

BY J. D. ROSS

Supt. of Lighting, Seattle

THE first part of the paper, after a short history of the science of light, is devoted to a series of experiments showing unassailable facts, and the writer has then drawn his own conclusions and presented his own theories on interatomic force. Very long light waves were first investigated with the hope of showing by analogy the mechanism of ordinary visible light and of heat.

Light is here understood to consist of, and include all transverse vibrations in the so-called ether, visible and invisible, and therefore includes electrical waves, ultra violet, X-rays and gamma rays.

The writer has found the field that his experiments have opened up to be so vast that the paper is very long. Its principal features are touched on in the following abstract.

A short history of the science of light is first given to show the conceptions of various scientists.

Very long light waves were first studied. The first experiments were on reflection, the writer believing it absurd to think of a light beam as simply bouncing off the surface of a mirror without some intermediate transformation of energy equivalent to the storing of energy in potential form with subsequent release to the kinetic energy of the reflected beam.

This action would be equivalent to the recoil of a spring. The simple idea of motion of atoms or molecules in this action seems impossible for various reasons. It is also untenable in the kinetic theory of heat and for instance in accounting for the selective absorption, transmission and radiation of heat and light waves where millions of atoms are affected by a simple way.

If we revolutionize our whole idea of matter, carrier of energy and consider it only an obstruction and if we consider the energy in matter as potential or latent while the energy in interspace is the real thing to consider we will get nearer the truth. We will then think of matter as the rocks and logs in a rushing torrent that tosses them from place to place as it sweeps forward.

The reflection of light is one of its most fascinating branches and one that has been left severely alone.

In the past years Sir Isaac Newton and Dr. Einstein have both claimed that light does not travel in waves but is projected through space. They are members of a good-sized school. Others like Faraday and Maxwell cling to the theory of a medium in space, across which waves or strains could travel. Faraday in his marvelous work had that mysterious intuition which American slang call a "hunch" and he was generally correct.

In combating the wave theory of light Newton said,

> To me the fundamental supposition itself seems impossible, namely that the waves or vibrations of any fluid, can, like the rays of light be propagated in straight lines without a continual and very extravagant bending and spreading every way into the quiescent medium where they are terminated by it. I mistake if there be not both experiment and demonstration to the contrary.

This quotation is particularly striking when read in the light of the following experiments.

The situation today is beautifully summed up by G. W. C. Kaye in his book, X-rays, page 248 where he says after a discussion of the pulse theories of Stokes and J. J. Thomson and of Planck's quantum theory,

> The difficulties conspicuous with the X-rays have merged into those which all classes of electromagnetic wave are found to present in greater or less degree and the full secret of the nature of X-rays will doubtless be revealed, when we find the key to the overshadowing problem of the mechanism of radiation in general. We have seen that the problem of the transference of energy by ether waves involves us in the conception of a "quantum" of energy, radiation traveling undissipated through space. The reconciliation of the idea with the older and well founded conception of spreading waves remains. The experimental evidence seems to indicate that both theories are true simultaneously, that radiant energy is both concentrated and indivisible and at the same time spreads and is divisible.
>
> The keynote of the old mechanics is in fact continuity; of the new mechanics, discontinuity. Any hope of a compromise between the two theories appears to involve concessions fatal to ether. We are left confronted with the riddle of modern physics.

In the search for evidence of the theory propounded in this paper, the first law considered was: A magnetic line of force cannot pierce a closed circuit without being absorbed as an electric current,—what then? The induced current will be affected by resistance, inductance and capacity. But resistance causes a loss. What if that resistance be made negligible? Where will the energy go? How will it escape? Here seemed to be the secret of reflection.

The writer attempted to reflect 60-cycle waves in line with these thoughts. There are 60 waves per second and they travel 186,000 miles in that time. They are therefore 3100 miles long.

Hertz used prisms and mirrors 6 ft. 6 in. high for his shortest waves of only a few feet in length. The writer attempted to reflect the power from the closed core of a 60-cycle transformer by using only a heavy aluminum ring as a short-circuited coil of one turn set at 45 deg. This ring weighed four pounds and was 10 in. in diameter with a 6 in. hole so that it could tilt

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Abstract of a paper to be presented at a meeting of the Seattle Section, A. I. E. E., November 16, 1920.

at any angle on the 2-in. by 2-in. core. A magnetic density of 50,000 to 100,000 lines was used.

The experiment was a perfect success. It spoke volumes in an unmistakable message. "This was the basis of the reflection of light." As Keats said "Then felt I like some watcher of the skies when a new planet swims into his ken."

It meant that a light wave traveled with the electromagnetic line head on, *i. e.* in the direction of propagation of a light wave, and that these waves at least were curved sharply in greater and greater sweeps with the distance and they were not straight, but were nevertheless light waves. They were the waves such as Newton said were needed before he would believe that light was not corpuscular, waves with "a continual and very extravagant bending and spreading every way into the quiescent medium where they are terminated by it," and this was the "experiment and demonstration," not "to the contrary" as he predicted, but confirming the existence of a medium in space more firmly than ever.

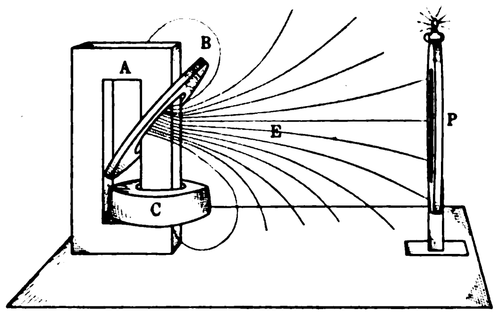

FIG. 1—REFLECTION OF LINES FROM A 60-CYCLE TRANSFORMER

A—Laminated steel core.
B—Ring mirror.
C—Exciting coil.
D—Exploring coil and lamp.
E—Magnetic or light wave.

These waves obeyed Oersted's law, much the same as we use in hydraulics for the flow in pipes, or for any flow or strain. The angles of incidence and reflection of the beam are equal as nearly as is compatible with Oersted's law.

It became plain that light goes from Oersted's law of distribution to the well-known law of inverse squares as the frequency rises as if inertia plays its part and the waves change from currents washing back and forth, to rapid beats on the ether. True vibratory waves are then formed.

The fact that magnetic materials carry long light waves 1000 or 1500 times better than free space pointed to a tremendous resistance to the trasmission of light in free space, just as light is retarded in passing through glass, and it pointed to a higher speed of light than 186,000 miles per second for long waves along iron. The iron acts as a core much as a copper wire acts as guide to an electric wave. It may however be more reasonable to suppose that these waves travel much slower than vibrating visible light, but become faster along iron and thus approach the speed of short rays in space.

Reflection need not take place on matter at all. A pencil of long light waves may strike a plane in free space and reflect on it without the presence of matter provided that such a plane is bounded by a closed circuit. The lower the frequency the more massive must be our mirror. We can reflect magnetic lines out of the core or after they have left the end of a bar magnet just as well with the frame of the mirror after it is removed as we can with the mirror itself providing the frame is metal or lined with metal making a closed circuit. Good conductors must be good reflectors because the efficiency of reflectors depends on electric conductivity.

Conduction of heat now becomes little different from radiant heat except that the ray is retarded as it passes through matter by successive absorptions as electric current and subsequent discharge as the reflected beam, *i. e.* as new lines of force. Good conductors of electricity must also be good conductors of heat, which is the case. Selective absorption and radiation show paths of characteristic length and a structure tending to aggregations larger than the molecule. The violent motion of molecules under heat and the so called Brownean movements of suspended particles are an effect and not the cause of heat or heat itself as we have thought.

Their motion is due to the repulsion of light which in turn is the same as the repulsion of currents out of phase as shown in the well-known repulsion effects of induced currents by Professor Elihu Thomson. In the reflection experiment above described it is difficult to hold the ring mirror in place due to the great repulsion. Heat is not carried by motion of molecules. They need not move at all. It is the alternate unloading of the heat wave or lines of force into an electric current and vice versa until the energy gets away at the surface, *i. e.* it is repeated reflection. Good conductors of electricity must be good conductors of heat.

The molecules are torn asunder if the energy becomes intense and the structure destroyed. In chemical action we must also consider a double breathing action of the induced currents tending to expand each half wave by repulsion since the current on opposite sides of an electric whirl go in opposite directions.

Matter is necessary in all these actions for the same reason that it is needed in an electric wave to act as a core or guide to the wave. The wave, however, is an ether wave. Matter in some way marks the path of the current and allows a slip or motion of the ether.

It became apparent that in the light of our two basic facts, a heavy metal plate brought near an electric current and having its edge parallel with the current would stop the magnetic lines which encircle it symmetrically and reflect them by absorption to electric current, followed by formation of new magnetic lines,

the reflected beam. Since these light waves in this case are circles around the wire, *i. e.*, magnetic lines, we would expect them to curve back to the plate repeatedly until they finally curved over and around its far edge. But here appears an action that Newton describes above as characteristic of a wave,"A continual and very extravagant bending and spreading every way into the quiescent medium where they are terminated by it." The waves become a compromise between an actual wave and a flow resembling the action of water poured on the same plate from the direction of the wire.

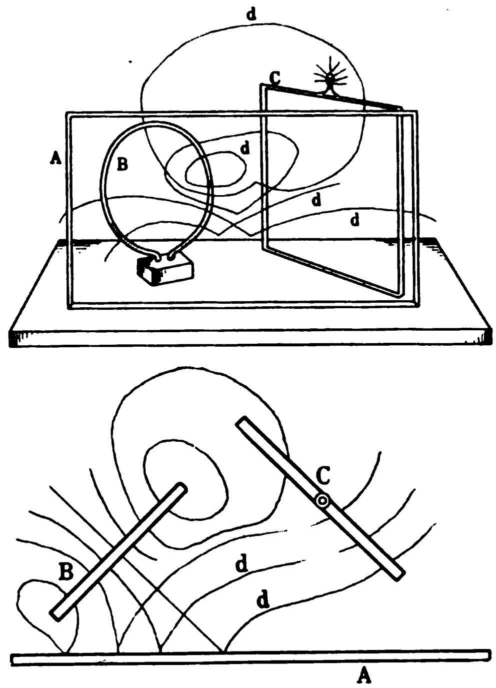

Fig. 2—Elevation and Plan of Reflection of Magnetic Lines(Curved Light) on a Plane in Free Space

A—Boundary of reflecting plane, a closed copper loop.
B—Radiating band oscillator.
C—Exploring band and lamp.
d, d, d,—Some of the curved lines generated by *B*, and reflected by the plane bounded by *A*. These lines are reflected through *C* and light the lamp.

We now see why a great radio wave being curved can encircle a mountain and return to its source, and why the earth being a poor conductor becomes semi-transparent and a poor reflector, and being irregular scatters the wave more than when it passes over water.

If there were holes in the above plate water would pour through, but these light rays cannot go through without violating the very law on which reflection is based, namely, that a line of force cannot pierce a closed circuit. The medium bends and sags as if the hole were a rubber sheet but cannot break. A single bounding closed circuit such as a heavy copper rectangle is as good as a solid plate. These waves act like the flow from a piston working back and forth in a cylinder open at both ends and immersed in water, while shorter visible light acts as if the piston were replaced with a diaphragm vibrating at tremendous speed, too fast for the inertia of the water.

This suggests that a tube would carry our long waves best and prevent them from curling into space and returning. If we try to make a line of force enter the end of a tube we encounter a closed circuit and the line is reflected. We must therefore make such a tube by bending the plate or closed loop spoken of above into the form of a tube with the edges overlapping but insulated. This presents no closed circuit until the wave tries to pierce the tube wall, when it is reflected. As expected there is more frequent reflection due to curved lines and also greater absorption resulting in low efficiency especially if the tube is thin.

A reflecting tube may be made by coiling a heavy sheet of copper around a cylinder making a tight spiral. It should be wound with a sheet of empire cloth to keep any two layers from touching. It should be ¾-in. thick. A laminated magnet may have one end inserted several inches into one end of the tube. The exciting coil should be placed close up to the tube to lessen leakage for we are increasing the reluctance and greater magnetomotive force is required. It is magnetomotive force that drives a light wave through space, and the reluctance or resistance of free space for this wave is over 1000 times that of iron.

The great amperage that such a tube must carry to reflect a 60-cycle wave makes it difficult to construct a tube that will not be disappointing except for plotting this region on various curves. To cast the tube and slot it is also troublesome. Vastly better results may be obtained with the 10-in. tubes described below using shorter waves and requiring very little metal in the tube walls.

Let us now digress by leaving this experiment for a little while, for we are working in the dark with this wave both literally and metaphorically, and we must have a means of easily exploring our magnetic field.

When we reflect the lines of force from a transformer core by an annular mirror we can explore the field outside by a coil and milliammeter. We can visualize our field better by using a coil of 250 or 500 turns of No. 10 wire carrying a 1½-volt flashlight lamp. We can bring this coil within about a foot without burning out the lamp and its varying brilliancy in different locations makes an excellent exploring system.

The writer has for years used a grounded heavy copper sheath between primary and secondary coils for protection on transformers of 60,000 to 125 volts for patrol stations and for insulating transformers used on high-tension telephone lines. This sheath has its edges overlapping and insulated to prevent a closed circuit. The delicate voice impulses pass readily through the metal at right angles with little loss. The power is now in the electrostatic lines, to which all substances may be transparent unless the edges trun back and touch, making the electrostatic line a radius of such a circuit. The writer considers

the electromagnetic wave as formed progressively from the electrostatic wave so that the magnetic line forms mostly outside of this sheath. The writer has arranged to show the development of the electric wave and light wave from a stationary static charge and demonstrate their relation in time and in the three dimensions of space. It may be sufficient in this abstract to say that a light wave of 60 cycles is made up like all others of two components at right angles, the electromagnetic and electrostatic fields. The two as shown by Maxwell's equations are equal, and the unit of the former divided by the unit of the latter is in the nature of a velocity which Maxwell showed to be the speed of light. These two forces and the electric current producing them, or induced by them, have their directions of propagations all at right angles to each other, *i. e.* they represent the three dimensions of space though all three tend to spread out into the other two dimensions. No two can bear a steady relation to each other in time, *i. e.* no two can be steadily coexistent in a cyclic current, but rise and fall at different times.

The light wave does not spring from the conducting wire. No current produces a magnetic line directly. It forms from the electrostatic line after it leaves the wire; an electrostatic line readily passes through a heavy metal plate with only the loss of the electromagnetic field developed in that short distance. An electromagnetic line cannot so pierce a plate; in other words a light wave may slip sidewise through a plate but not head on. We may place a string as the center of a light wave, or better an elastic band, and let it carry a disk with a torsional motion from side to side. The energy is then alternately kinetic and potential. The radius of the disk is the electrostatic line; the elastic band is the magnetic line and direction of propagation of the wave. The rim of the disk tends to be the electric current whenever it meets a conductor. The right and left rotations of the disk give an alternating current.

It is evident that the magnetic line or elastic band and the electric current or rim of the disk do not touch, or originate directly from each other.

It is hard to see how Newton and recently Einstein can be correct in stating that light is corpuscular, as it would spring from the wire radially like the electrostatic lines. The above illustration is very incomplete. The elastic band merely represents a direction. We would have to consider changes in all three forces and think of our disk as a smoke ring expanding and contracting and continually turning inside out but always touching the circumference of the wire. The illustration is given however to better understand the following experiment, which is beautiful to say the least.

A coil carrying a 1½-volt flashlight lamp is moved back and forth along and over the outside of the copper reflecting tube. It lights up and its varying brilliancy is a measure of the absorption of the beam traveling inside. Our disks readily come through the tube and induce a current in the coil, but when our elastic band bends and touches the tube it cannot go through. The disks are the only part that can induce a current. When they cut the tube at right angles they lie in the plane of an electric circuit, but it is not quite closed for the tube is slit down its length, so the tube wall is transparent. Now let the elastic band or magnetic line try to get out through the tube wall. As soon as it bends, the plane of the disks will change, for they are always at right angles to the band. If the band tries to pierce the side of the tube the disks must cross in the plane of the tube wall and the rim will lie wholly in metal, forming a complete circuit. This induces a current which throws out a new magnetic line, the reflected beam. Our exploring coil and lamp are only a mirror of high resistance with correspondingly low efficiency. A heavy short-circuited coil in its place stops the beam and reflects it on itself for the same reason that the beam cannot pierce the tube.

The efficiency of reflection at 60 cycles is of course very poor, but much better than expected. The mirror of course heats up. A short-circuited coil of wire makes a good reflector, but being a short circuit, does not allow of more than a minute's work at a time. A plate of aluminum needs to be about ¼ in. thick at least, and the thickness for other metals is inversely proportional to their conductivity. Thinner plates are more or less transparent. The necessary thickness also depends on the density of the lines of force of the light wave.

The writer therefore changed the design to produce a short efficient wave that would not enter deeply into the mirror. The apparatus consists of a small condenser and short spark gap in series with a 10-in. copper band of flat No. 6 wire, the condenser is supplied with 20,000 volts. The exploring loop is also a 10-in. or 12-in. band carrying a 1½-volt lamp. The mirrors are 10-in. or 12-in. complete bands soldered at the joint. The reflecting tubes are a little smaller and from 4 ft. to 10 ft long. as desired. The radiating band is better taped with one turn of empire cloth, and the end of the reflecting tube is brought near or is fitted inside the band.

The first tube was made by soldering No. 6 flat wire to form a network of 10-in. by 10-in. mesh. The edges were insulated and taped together. The tube was 8 ft. long. A taped band carrying a lamp was fitted tightly on the end of the tube. The lamp burned out, though one on a 12-in. band would not even light. The lines outside bent sharply back under the band and neutralized those inside the tube, the result on the lamp being zero. The 12-in. band was then moved over the tube toward the radiator and concentric with it. The lamp

was now gradually lighted showing a rather steep gradient of the lines to meet the curved lines on the other side of the radiating band.

Another tube was added at the end of the first and a collar with overlapping insulated edges was used to join them. Here we meet with a great surprise. Only when the collar is made of very flexible screen or foil tightly fitted over very thin insulation can any considerable radiation be forced into the second tube. The lines leak out through the thickness of paper. The whole operation reminds the observer very strongly of trying to mend a leaky joint of water pipe under heavy pressure. The writer considers the condition completely analogous.

Joints may be made tight by soldering wires across the joint such as to make it impossible to leak without piercing closed loops. Two wires or bands at the edges are sufficient if insulated and taped close together.

A 5-in. exploring band and lamp inside the tube shows that the field is intense at the intersections of the wires for reasons that are plain if the direction of induced currents is traced out. In passing the 10-in openings the lines sag outside due to their pressure or repulsion until the lamp fails to light.

The presence of a reflecting tube does not produce the effect expected on the assumption that lines tend to contract like an elastic band under strain. The lines on the other side of the radiating band do not change materially when the reflecting tube is introduced an inch away.

Cones similarly made were substituted for the tubes with great success and the lines were concentrated through a small aperture. A trough or half tube was used. It conducted the lines two or three times the normal distance before they escaped over the sides.

It may be argued that some other action, other than reflection, may give these results. To test this the radiating band was set in the center of a table and a square 12-in. by 12-in. receiving band with lamp was placed at right angles to it several inches away so that one of its vertical sides lay in the plane of the radiator. The two were placed far enough apart to prevent the lamp from lighting due to the curved lines passing through its loop. A rectangular closed band of No. 6 wire 12-in by 18-in. was used as a mirror and placed as the hypothenuse of the right angle. This made it at an angle of 45 deg. to the radiator. The lines of force are reflected through the lamp loop and the lamp may easily be burned out.

This experiment again shows four facts without the shadow of a doubt. The direction of propagation of a magnetic line and of light are identical, in other words a magnetic line with its attendant electrostatic field is an ordinary light wave with the magnetic line head on. The angle of incidence and reflection are equal. Reflection requires the conversion of the incident beam to electric current and the conversion of this current back to the reflected light beam. Therefore light travels in circuits tending to close and is not straight.

We have all considered light waves as radiating directly from an oscillator, the magnetic lines forming a series of bands directly across its path. Now we must consider light waves as circles around our wire. The extent to which these giant waves hold their shape can be easily worked out and should be studied. Apparently they lose their symmetry and degenerate more into a flow along the shortest return path, easily going around conducting objects by reflection and easily eddying around behind objects into the unstrained medium.

The analogy between long sound waves and long light waves in this respect is complete, for both cast indistinct shadows.

In a mixed sound beam of high and low pitch the base notes can be heard behind a building when the high notes cannot. The writer considers the medium to be much the same for light as for sound, a divisible material under pressure.

Mirrors may be made of loops, screen, sheet metal, or looking-glass. The surfaces need not be regular or polished. Wet boards, or other objects are also partially opaque and so will reflect very slightly, their action being best of course in the presence of dissolved salts, acids, or alkalis, and when acting on the longest waves.

Shadows are particularly interesting for they cannot be made distinct. The wave will curl through everything but a closed electric circuit. A 6-in. copper plate may be set in front of the radiator as an opaque screen and a lamp on a 5-in. loop can be lighted 3 in. behind its center. Solid plates should be used for screens. A loop allows the other to sag, so far that a concentric smaller loop lights up, close behind it. The electrostatic field must go to the loop to induce a current, and back before reflection can take place. If the loop is too large the first wave will pass before it can act; this is selective transparency, a part only of each wave passing through. By plotting the sag behind a loop we can measure the lateral speed of electrostatic lines. If they are longitudinal thrusts they will travel faster than light.

The action of these waves much resembles the action of the electric current itself, especially when they conduct along an iron core. The inducing of an electric current merely means that a light wave slips sidewise along a wire. It is the first half of the process of reflection. Similiarly if a light wave could slip sidewise in space it would create an electric potential. This is magnetic induction. The wire moves instead of the wave.

A light wave may not be a sine wave; a storage battery may be used to send an intermittent current into a coil of a laminated magnet and produce reflection that will light lamps like an alternating current.

In all experiments on 60 cycles the lamp may be

replaced by a coil and ammeter, or for remote regions, a telephone receiver. Shorter waves may be explored with a thermocouple, a detector, a wire resistance or hot wire ammeter, or a neon tube. The field can be very accurately plotted.

Experiments are being conducted on refraction through various insulating substances, liquid and solid. Refraction is least for long waves and lines would not cross at a focus but would turn back in curves so that refraction is difficult.

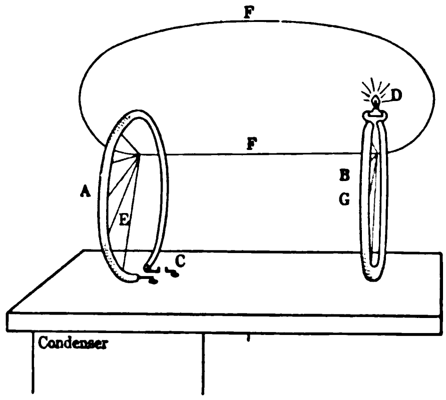

FIG. 3—ELECTROSTATIC LINES MAY PIERCE SOLID METAL

A—Heavy copper tube used as conduit enclosing insulated ring oscillator.
B—Heavy copper tube enclosing insulated exploring coil.
C—Spark gap.
D—1½-volt lamp.
E—Electrostatic lines coming from oscillator and generating electromagnetic line *F*.
G—Electrostatic lines generated by *F* which, after piercing tube *B* generate electric current in exploring coil. Part of *F* is reflected by lamp circuit.

Stationary waves in tubes are also being studied in an attempt to measure the speed of the waves along iron as compared with the same waves in space.

Of course it is understood that a stationary magnetic line from a direct-current magnet cannot be reflected except at the time it pierces a mirror, *i. e.*, while it is varying in intensity. It requires lateral motion of a magnetic line or matter in its neighborhood, to produce the electrostatic field.

The relation of these two fields is further shown by the high-voltage 10-in. band oscillator above described. Both this and its receiving band may be each encased in a heavy copper tube and the lamp still lights by induction through both tubes. See Fig. 3.

SPEED OF PROPAGATION

We have seen that light is retarded in free space and long waves seem to travel faster along iron.

We know that a static electric charge may travel at snail's pace or less along glass or sulphur and can have all speeds up to the speed of light.

These facts suggest experiment to see if the electrostatic field moving at right angles to the electromagnetic line or light ray travels at a higher speed, since it resembles a thrust or longitudinal wave. A loop reflector is interesting in this respect.

Referring to Fig. 4, let *A* represent a fixed band across which is stretched an elastic membrane. The arrow *C* in its flight will move past the ring until its energy is all taken up and becomes potential. It stops entirely for a moment, then moves backward gathering force until it is shot clear of the ring. This is reflection. When the arrow struck the membrane an impulse radiated along the membrane to the ring, and reaching the ring returned to react against the arrow and throw it back. The time intervals of the arrow in moving from the ring center *O* to *D* are nearly the same as the impulse takes to reach the ring *A* and return.

Our ring here represents an electric conductor in which a current is induced. The elastic membrane is the electrostatic field and the arrow is the electromagnetic or moving magnetic line of force or light ray. The only material substance here is the ring *A*.

The magnetic line *C* should travel the distance *O D* while the electrostatic field travels twice the distance *A O* or the diameter of the circle, or more properly a line between the distances *A O E* and *A D E*.

The speed of the arrow, if we neglect the loss of reflection (analogous to ohmic loss), is between its speed at *O* and at *D*, less than the speed of light.

The detail of experiments cannot be given here, but two annular split rings or wire boundaries were used as shields to get a pencil of rays in the center of a closed loop but protect the loop on both sides from actual contact with lines. The two shields were joined by a copper strip making a split cylinder. In this cage the sag of a closed loop was roughly measured with a smaller exploring coil brought up behind it until the lamp began to glow. This action corresponds to bringing the smaller ring and lamp just inside the strained membrane *A D E* in Fig. 4, so that the impulse of the membrane would strike it before it struck ring *A*.

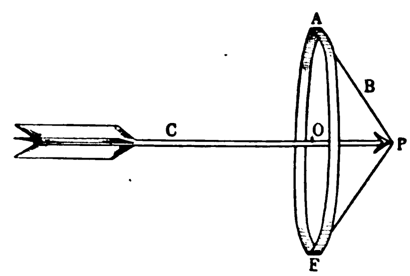

FIG. 4—SAGGING OF REFLECTING PLANES

From these preliminary trials as a forerunner of careful measurements it appears that the speed of the electrostatic lines is not materially different from the speed of light. The lighting of the lamp occurs with the distances *O D*: *A E* in the ratio of about 1 : 2, but better methods may show the two speeds to be identical.

The Absolute Zero

The absolute zero is—273 deg. cent. All heat has then been extracted from matter, and according to modern theory it would be quiescent throughout its mass. Charles' law shows that a gas contracts 1/273 of its 0 deg. cent. volume for every degree it is cooled, so that at absolute zero it would have contracted 273/273 of its volume and vanished. But under the kinetic theory of heat we have thought of molecules striking each other and passing the energy along, so we say that when a gas liquefies or solidifies, it nullifies Charles' law below that point.

The writer since his high school days has doubted this theory, but his only reason was the thought that solidification was only an accident as far as Charles' law is concerned.

More light was thrown on the subject when it was discovered that the electric resistance of the various metals decreases with lowering temperature at a rate that brings all currents to zero at approximately —273 deg. cent., *i. e.* 0 deg. K.

The interest in this discovery was enormously increased when Onnes at the Leiden Laboratory recently tested the electric resistance of a number of metals in liquid helium.

He found that mercury, tin and lead showed a decrease of 0.4 per cent per degree cent. from 0 deg. to a very low temperature. The decrease at a low temperature becomes less rapid until at a "critical temperature" which is 4.2 deg. K. for mercury, 3.8 deg. K. for tin, and 6 deg. K. for lead, the resistance suddenly drops to less than 2×10^{-11} times its 0 deg. cent. value, in range of 0.01 deg. cent. The metals are then called super-conducting. One thousand amperes per sq. mm. fail to sensibly heat small mercury wires and 600 amperes through lead wires give the same result.

At a certain critical current the wire regains its normal resistance. Unlike these metals, gold, platinum, and iron tend to approach a definite resistance down to the lowest temperature yet reached, 3 deg. K.

A current was induced in a coil of wire in liquid helium of 0.4 to 0.6 amperes, and persisted for four days decreasing about 1 per cent per hour. The remarkable lesson from these facts is that some elements near the absolute zero are subject to sudden changes in resistance, and there is a possibility of sudden changes at still lower temperature since various metals show this action at different degrees. A very considerable final change at the absolute zero such as is predicted by resistance curves with decreasing temperature, and by Charles' law is not improbable.

If temperature resistance curves have been correctly projected to a zero point at absolute zero and metals at that point no longer have ohmic resistance, it follows that all the electric current that man could generate could be carried without loss or heating, by a wire the size of a hair, in other words it means that if a wire once reaches absolute zero we could not again warm it by passing a current through it.

The above experiments bring out the startling fact that radiant heat would not warm it either, for at absolute zero the mirrors would have no electrical resistance and it follows that they would be perfect radiators without absorption or loss. If we focused the heat of the sun on them we could not warm them and they would reflect all energy they received.

Again if the writers theory of the conduction of heat be found correct, the conductivity of heat at very low temperature would be the same for various metals as for electric conductivity, and when the tiny electric whirls met no resistance at absolute zero, conductivity of heat would be perfect and none would be retained; all would simply work through and radiate into space. It follows then that matter once chilled to absolute zero cannot be revivified by even a white-hot object touching it.

How then can we again warm material so chilled? Perhaps by impact or friction of some sort. In any case such conclusions point to a total change of conditions at absolute zero and matter ceases to be matter as we understand it. Naturally it is almost impossible to extract the last few degrees of heat, but the total extraction of heat from a quantity of matter would be an achievement well worth tremendous effort. Some of the results near the absolute zero would be amazing. For instance if a small closed core transformer carrying a reflector ring, as its secondary, as illustrated in Fig. 1 were placed in liquid helium the primary would take enormous current and the ring reflector would become more and more efficient as the temperature was lowered, until at absolute zero all the magnetic lines would be reflected from the core into space and the entire energy of the primary coil would be reflected into space as curved light waves.

Let us now consider the latest research into the constitution of matter. The generally accepted theory of the atom is that it is made up of a positive electric charge as nucleus, which has negative electrons or electric charges revolving around or near it. These moving charges are equivalent to electric whirls or circuits.

Lorenz and other physicists consider the negative electrons as satellites in a plane, while some chemists like Dr. Langmuir think of them as revolving around fixed points of a symmetrical figure of three dimensions.

Two forces are in equilibrium and opposing each other. The negative electrons are kept from flying off by the attraction of the positive nucleus, and are kept from falling to that nucleus by some unknown force. The writer believes this force to be heat.

But whatever the form of the atom, if the above theory be considered it follows that when a line of force pierces such an electron orbit, it will be absorbed, then reflected, and the orbit will dilate, since the

charges on opposite sides of the orbit move in opposite directions and parallel currents or charges in opposite directions repel each other. On the other hand, when lines of force or rays of light or heat, which ever name we wish to give them, are gradually withdrawn, *i. e.*, when the substance is gradually cooled, we can think of the atom shrinking and the negative electrons slowly settling down closer and closer to the positive nucleus, perhaps in quantum steps, until at absolute zero the positive and negative parts are together and their static and magnetic fields are closed. They now become dead matter in the sense that a closed magnetized ring shows no magnetic field in the surrounding space, and in the sense that two condenser plates tight against each other send out practically no electrostatic lines into space. If a section be cut out of the ring magnet, or if one condenser plate be lifted at right angles to the other, like the wireless aerial, we at once have a positive and negative electromagnetic and electrostatic influence that makes itself felt throughout the universe.

It is of interest to note that the theory of negative electrons revolving around a positive nucleus is a theory of the constitution of the atom that is often accepted, and it has been suggested that a light ray is emitted when a negative electron moves from one orbit to another. This idea in effect suggests that the diameter of an atom is variable in irregular steps.

The writer's idea that the atoms close at absolute zero is his reason for believing that heat is the force which holds the electrons out from the positive nucleus, since all heat is extracted at absolute zero and a change of matter seems inevitable. Mass seems to be due only to electrostatic and electromagnetic forces, so the neutralizing of these would de-materialize matter and such de-materialized matter could not be detected by the senses or by any known instruments.

It must not be thought that all energy is extracted from such a de-materialized atom for heat is an insignificant portion of the energy of the atom.

The question is, can matter, so neutralized, be the ether of space and if so is the final change at absolute zero a falling away from the complex atom to a simple primary form, as simple as the hydrogen or helium atom, or simpler?

Structure of Space

Scientists are divided as to the structure of space; some believe in a medium, the so-called ether of space, others do not. Neither school has proved its claim, so both are equally entitled to their beliefs. The experiments above described seem to the writer to indicate a medium for the transmission of light consisting of small units or atoms under a pressure beyond our conception, that pressure being due to the average velocity of the ether particles, the ether being somewhat similar in its nature to a gas under pressure.

There may however be a system of mechanics with no analogy within our intelligence, and so perhaps incomprehensible to us.

The idea of an ether under pressure would mean that matter in many cases at least, was an obstruction to, not a container of energy and that the attraction of magnetic poles was due to the convergence of ether streams driving matter forward. This of course has no reference to the internal or inherent energy of matter. It may be objected that this would require an additional dimension or outlet. Whatever the objections raised against the theory, it certainly explains much more than the elastic solid theory.

There is a tremendous resistance in space to the passage of light at least to long waves, a thousand times more than along iron so that the passage of a wave through space may not be as simple as we imagine.

The idea of ether under pressure, makes quite logical the idea of actual flow at very low frequencies, changing to pulses or beats at higher frequencies where inertia comes into play, and finally, very minute waves of atomic size, like X-rays or gamma rays, may easily act on one unit or atom of ether and send it out like a projectile into space, "radiation traveling undissipated." It is then "corpuscular." Magnetic lines in the same direction repel only because they form an area of high pressure and try to relieve that pressure. Magnetic lines tend to contract only to equalize the pressure as the air in front of a fan forms similar pressure gradients or lines of force in filling in behind the fan, and in the same way that wind moves from an area of high pressure to one of low pressure. Since a small mirror will reflect its part of a giant wave it follows that there might easily be a scattering of an electric wave traveling along a wire in the possible local channels in its substance, or the current in a turbulent stream might be diverted into a multitude of eddies. This is ohmic loss. Conducted heat is a multitude of such electric currents emitting and reflecting repeatedly at all angles their characteristic or synchronous waves. These small systems and the main electric wave in our experiment differ only in size, just as our magnetic waves differ from visible light. This explains also selective radiation and absorption. Evidently these small circuits and the waves emitted resist the movement of the main current along a wire until they are eliminated at the absolute zero by some change in structure. On the other hand if the intensity of the electric current or any heat source is increased, some of the paths are broken up into smaller ones and the material becomes luminous. If the operation is increased to its limit probably all matter disintegrates to its primary substances. Heat determines the condition and physical attributes of matter. When heat is withdrawn matter ceases to have physical attributes.

If matter at absolute zero becomes a perfect conconductor of heat and electricity and if matter at absolute zero becomes the ether of space then space should conduct heat and electricity without loss. This is fulfilled in the transmission of radiant heat and in the

streams of electrons that cross from the sun to the earth without loss.

Each time we study matter and energy we find that our many chemical elements simplify to a less number, and our many forces also become fewer. Each time we hold the torch higher and peer further back, into the mystery we find creation coming closer to its origin. Our religion and our reason dictate that it was formed from nothing.

Dr. Einstein speaks of "space relations" as force. All matter is conceded to be stabilized energy. All our forces are merging into different aspects of the same one, but beyond this we have not been able to get any physical conception as to what energy is.

It is a known fact that an electrostatic charge or field in motion produces an electromagnetic line of force and a magnetic line of force moved ever so slightly produces electrostatic lines. These lines on the slightest motion produce an electric potential or current. The three forces represent the three dimensions of space. To that extent they are space relations whatever that means. Otherwise they are apparently compound and interlinked motions of a medium in space. Our modern experiments and theories of matter show it to contain nothing beyond these three forces. All the forces of nature deal with matter, so deal with only these three and it looks as if all forces contained only one or more of them. Cohesion and adhesion are not existent in matter. Tensile strength is the strength of interspace and it is the the interspace that finally breaks.

Again anyone of the three, plus motion, produces both the others. This looks as if they were aspects of the same thing and that the starting point of all creation is simple to an amazing degree. These facts are known but, so far, are little realized, for science has more than trebled her knowledge in the last few years and discoveries have come too fast to allow of realizing their meaning. The conservatism of the world also forbids.

Life is evidently intended to be the formation of indelible concepts of a solidity and reality that, from a scientific standpoint, are not what they seem. Our old theories should all be reviewed.

Ether may still be capable of being reopened as matter by radiation, or some other way. The writer expressed this thought before the Am. Chem. Soc. in 1918 and the Sigma Psi Society in 1919 at Seattle that the star dust of space was an evidence of continual recreation, and re-opening of the ether and the vast nebulae as of space were being continually produced. The foundation of worlds is then possible in new places from material transported without the interference of gravity. This work then becomes cyclic like everything else, only on a more magnificent scale in space and time.

Unfortunately it is difficult to find what if anything happens to the cold worlds of space or whether it is possible for parts of them to reach the absolute zero at any time and go to pieces.

That a nebula is only now drawing up into a world is difficult to reconcile with an infinite past, unless we consider it as recently brought to life and endowed with the force of gravity. The conception of such an ether particle is much like that of Dr. Langmuir's quantel arrived at from another angle.

If all space is filled uniformly, as Bergman's philosophy insists, then we can have a medium, each particle of which may be endowed with motion, the average of all being an unvarying pressure and capable of moving at high speed from an area of high pressure to an area of low pressure, producing by convergence the so-called attraction and repulsion of magnets and the attraction of gravity.

This theory would require that internal energy of a pound avoirdupois of matter after deducting its heat energy would exist in the quantity ether from which it came or to which it returns. The ether of space has been considered to posses mass and inertia. This thought is hard to reconcile but the various phenomena attributed to the ether show at least an equivalent property and therefore some resemblance to matter.

The latent internal energy in a pound of matter cannot be accurately computed and all we can find so far on the subject is the power liberated when radio active elements disintegrate. Radium teaches us most on account of its rapid disintegration. Rutherford estimates a liberation of from 2×10^9 to 5×10^{10} gram-calories from one gram of radium in degenerating to helium and probably to lead. This amounts to from 1,050,000 to 26,350,000 kilowatt-hours per pound avoirdupois. But beside this energy so liberated we still have the disintegration products helium and lead which are also supposed to have further enormous internal energy, for like radium they too are made up of positive end negative electric charges. Since they are not strongly radio active we have no way so far to compute their energy. The loss of weight of radium cannot so far be measured, as available amounts are too small, and the time since the discovery of the metal is too short for any reliable measurement. We cannot even guess if the change of atomic weight is any measure of the energy liberated or if the lead and helium weigh less than the radium from which they degenerate.

On the other hand if a pound avoirdupois of matter were to be accelerated to the speed of light, 186,000 miles per second, it would contain, due to this velocity 564,083,427 kilowatt-hours or 21.4 times the higher figure given by Rutherford as the amount of energy liberated from a pound of radium in changing to helium and lead.

It is evident that if matter vanishes at absolute zero it still holds a vast energy as the ether of space. This energy might be partly in velocity and partly in a form equivalent to mass.

Summary

The writer shows experimentally the following facts:

1. Reflection is not a simple operation. The re-

flected beam is not a continuation of the incident beam, there being an intermediate transformation of energy, light to electric current, and electric current to light.

2. Light, with the exception of very short rays, does not travel in straight lines but travels in closed circuits tending to come back to the starting point.

3. A moving magnetic line of force and light ray are identical and their direction of propagation is the same.

4. Very long light waves obey Oersted's law instead of the law of inverse squares. The shorter the wave, the further it leaves Oersted's law, and the closer it obeys the law of inverse squares, up to the wave lengths somewhat beyond ultra violet; after that, light seems to be corpuscular the rays being so short that they act on single ether particles.

5. The phenomenon of repulsion of light is identical with the repulsion of unlike magnetic poles, and is a difference of phase relation between the light wave and the electric current it induces. It is identical with the repulsion between the primary and secondary currents of a transformer.

6. The kinetic theory of heat is untenable. The so-called Brownean movements of suspended particles prove intense vibration in the particles of matter, but that vibration is the effect, not the cause of heat. It is the effect of the repulsion of light, the repulsion due to phase difference. Conduction of heat is repeated reflection of radiant energy.

7. An electric current is not the direct source of a magnetic line. The electrostatic and electromagnetic fields of a changing electric current are produced progressively, not simultaneously, the electrostatic field being first produced and the electromagnetic field being in turn produced from it.

8. Conversely a magnetic line does not generate an electric current except through the medium of the electrostatic field at right angles to it.

9. Very long light waves may be generated at a point and conducted along magnetic substances as a core or guide, just as an electric current travels along a wire, except that the direction of propagation of an electric current and light wave differ in space by 90 deg. These waves may also be conducted by reflection.

10. Except in cases of selective absorption the efficiency of a reflector is the same as the electric conductivity of the material from which it is made, *i. e.*, the loss in reflecting a beam of light is ohmic loss in the reflector.

From these facts and the facts and theories of eminent scientists the writer deduces the following assumptions:

1. Light meets tremendous opposition in free space. In the case of long light waves this is over 1000 times greater than in iron.

2. Long light waves in iron travel faster than the so-called speed of light.

3. The electrostatic or lateral field of a light wave may be more of a longitudinal impulse, and may be found to travel faster than a light wave in its direction at 90 deg. to the wave.

4. Very long light waves are of the order of displacement currents. As the frequency rises, waves become more and more a vibration rather than a current. X-rays are copuscular.

5. There is an ether of space, a divisible material under enormous pressure, not an elastic solid as generally supposed, though it is highly elastic.

6. Matter disappears at the absolute zero. Charles' law holds at all low temperatures. Heat is the force that holds the negative electrons of an atom away from the positive nucleus. When heat is entirely withdrawn the opposite charges are together, and the electromagnetic and electrostatic fields are closed or nearly closed. These fields give matter its properties.

At the absolute zero matter cannot be again warmed by electric resistance, by conduction of heat or by concentration of heat rays. The complex atoms have dissociated to the simpler or primary form, not amenable to the laws of matter and the electrostatic and electromagnetic fields are closed or nearly so.

7. Matter when it reaches the absolute zero, *i. e.*, when all heat is withdrawn becomes the ether of space. Matter is a special form of the ether.

8. Gravity is a function of the electromagnetic and electrostatic forces and so disappears at the absolute zero when these fields close or become exceedingly small.

9. Matter is being continually formed by the opening up of the fields of the ether particle, thereby forming the atoms of matter. The continual formation of matter is shown in the formation of star dust and nebulae which often consist of the simplest elements.

10. The energy of heat is insignificant compared with the internal energy of matter. The enormous internal energy of matter as exhibited in radio active elements then becomes the energy of the ether and may occupy still less space. Mass changes largely to velocity of the ether particle, this velocity being a function of the speed of light. There is still left something akin to mass and inertia.

11. Matter and the ether can act on or "grip" each other only at high relative velocity. This presupposes ordinary magnetic lines to be moving streams at high velocity.

Ether will not slow up a comet though it consists of the thinnest and finest dust, but moves a conducting wire or a magnet with tremendous force.

12. All matter and energy finally resolve into three forms representing the three dimensions of space, namely electric current, the electrostatic field and the electromagnetic field.

The full paper and detail of apparatus and these and subsequent experiments will shortly appear in book form.

Abstractive and Selective Properties of Radio Antenna Circuits

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1. *Introductory*: This paper is an analytical study of the power abstractive and selective properties of simple series radio antenna circuits.[1] It does not deal with the properties of coupled circuits, or of amplifying circuits, or of differentially connected circuits which utilize a difference in the direction of propagation of the waves from the correspondent station and the interferent sources to reduce interference. A discussion of the selective properties of the simple series circuit is a necessary, or at least a very helpful, preliminary to the treatment of coupled, amplifying and differentially connected circuits.

The present paper is a continuation of the studies appearing in two former papers: the first paper[2] showing that the radiating and ultimate abstracting powers of a high power extended horizontal network are both independent (within limits) of the mounting heights of the network, and the second paper[3] dealing with the computation of the wasteful resistances of extended antennas. The present paper is devoted to a consideration of the properties of the simple series antenna circuit, with the object of determining the circuit proportions and frequencies which will make the circuit most highly responsive to the correspondent's signal and unresponsive to interferent sources.

2. *Basis of comparison of receiving circuits. Method of treating the detector.* The second paper referred to above concludes as follows: "The relative merit of high and low antennas is determined not alone by the radiating and absorbing efficiencies of the two types but also by considerations having to do with the power generating devices and the selective reception of signals under the conditions of commercial operation. For example: the function of a receiving antenna is not simply to deliver to a detecting device energy abstracted from impinging waves. Its function is to *selectively* abstract energy from the impinging waves and to deliver it to the detecting device. The ultimate comparison of the relative merits of the two antennas for receiving purposes under the conditions to be met in commercial operation must be a comparison of the amounts of energy delivered to the detectors from the desired correspondent when the strengths of the interfering signals or noises have been reduced to the same intensity in the two cases."

We now propose to make a comparison of the relative amounts of energy delivered by a sustained wave correspondent station and by different interferent sources to resistor detectors associated with antennas of various forms when operated at various frequencies. To permit of a general mathematical treatment of the circuits, it is assumed that any detector, no matter how it may draw energy from the oscillating circuit, (whether as an ordinary resistance, as in the Fessenden hot wire barretter; or at a more than proportionally greater rate at the peak of the voltage, as in the audion; or intermittently, as in the Poulsen ticker) may, *in its effect upon the oscillation of the circuit,* be replaced by a resistance connected in series in the circuit. Such an equivalent resistance will be referred to as a *resistor detector*. The resistance assigned to such a detector must be such that the average power expenditure in the resistor is equal to the average power expenditure in the actual detector.

It is further assumed that the power from the correspondent station delivered by a circuit to such a resistor detector, or the energy delivered to the detector in a given interval, is the measure of the merit of the circuit. In other words, the thing necessary to the operation of any detector is the supply of energy to it at a definite rate. If a circuit, or combination of circuits, will supply the necessary energy—after sifting out the energy from the interferent sources—it is always possible by means of a transformer to adapt this energy to the voltage current requirements of any detector.

3. It may be well at this point to note the methods of associating a detector with a circuit and the conditions to be fulfilled under each method in order to make the delivery of power to the detector a maximum. The circuit with which the detector is to be associated may be either the antenna circuit itself, or a secondary or a tertiary circuit. Fig. 1, 2, and 3 illustrates the simplest case, the case in which the detector is associated directly with the antenna. The statement of the conditions to be fulfilled applies only to the reception of undamped waves and for the case in which the time constant of the receiving antenna does not exceed 0.2 of the Morse dot interval.

When receiving undamped waves with a given antenna the power expenditure in a series resistor detector (Fig. 1) is a maximum if the resistance of the detector is made equal to the antenna resistance R_a. (The

1. This study was carried out with the support of the International Radio Telegraph Co. I have embodied in the paper constructive suggestions contributed by H. M. Crothers and L. J. Peters of the University of Wisconsin.

2. "High Versus Low Antennas in Radio Telegraphy and Telephony" by Edward Bennett, *Bulletin* of the University of Wisconsin, number 810, Engineering Series, Vol. 8, Sept. 1916.

3. "Feasibility of the Low Antenna in Radio Telegraphy," by Edward Bennett, *Proc. Inst. Radio Eng.*, Vol. 6, October 1918.

antenna resistance R_a is the sum of the radiation resistance R_r plus the wasteful resistance R_w.) Under these conditions the power expenditure in the detector is $E^2/4\,R_a$ in which E represents the r. m. s. value of the voltage induced in the antenna by the impinging waves.

If the resistor detector, instead of being connected

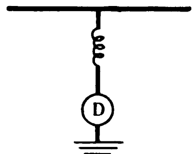

FIG. 1
R_d should equal $(R_w + R_r)$

in series in the circuit, is connected in shunt to the antenna inductance as in Fig. 2 the detector resistance should have the following value in order to lead to the same power absorption.

$$R_d \text{ should equal } \frac{R_c^2}{4\,R_a}$$

in which R_c is the critical resistance $2\sqrt{\frac{L}{C}}$ of the circuit.

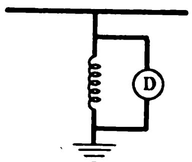

FIG. 2
R_d should equal $\frac{R_c^2}{4\,(R_w + R_r)}$

If the resistance of a given type of detector is (n) times the antenna resistance, it can be connected as in Fig. 3 in the secondary of a transformer. With the transformer connection, the following relations

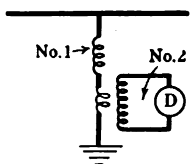

FIG. 3
X_2/X_1 should equal R_2/R_1
X_m " " $\sqrt{X_1 X_2 + R_1 R_2}$

should be satisfied if the power expenditure above noted is to be obtained in the detector.

$$\frac{X_2}{X_1} \text{ should equal } \frac{R_2}{R_1}$$

$$X_m \quad \text{"} \quad \text{"} \quad \sqrt{X_1 X_2 + R_1 R_2}$$

R_2 is the resistance of the secondary, mainly the detector resistance.

R_1 is the antenna resistance R_a

X_2 and X_1 are the net reactances of the secondary and primary circuits. If X_1 is inductive, X_2 must be inductive, if X_1 is condensive X_2 must be made condensive.

X_m is the mutual reactance between primary and secondary circuits.

4. *Classification of correspondent and interferent combinations.* The following is a classification of the correspondent and interferent combinations which are encountered in the operation of radio stations.

TABLE I

CORRESPONDENT AND INTERFERENT COMBINATIONS

I. Correspondent—a sustained wave station.
  1. Interferent—a sustained wave station.
    A. Slightly detuned, say by 1 per cent.
    B. Greatly detuned, say by an octave.
  2. Interferent—a spark station
    A. Of the same frequency
    B. Slightly detuned, 1 per cent
    C. Greatly detuned, an octave.
  3. Interferent—a suddenly applied and long sustained induced voltage, or the sudden release of a bound charge.
  4. Interferent—an induced voltage impulse.

II. Correspondent—a spark station.
  1. Interferent—a sustained wave station.
    A. Tuned to the same frequency.
    B. Slightly detuned, 1 per cent.
    C. Greatly detuned, an octave.
  2. Interferent—a spark station.
    A. Slightly detuned, 1 per cent.
    B. Greatly detuned, an octave.
  3. Interferent—a suddenly applied and long sustained induced voltage, or the sudden release of a bound charge.
  4. Interferent—an induced voltage impulse.

The subsequent discussion will be limited to the case in which the correspondent station is a sustained wave station.

5. *Relative response of simple series antenna circuits to undamped detuned waves; three numerical illustrations.* As a preliminary numerical illustration of the subsequent discussion, let us consider three antenna circuits with the detector represented as an ohmic resistance directly in series in the antenna, as in Fig. 1.

Antenna H is the Darien Naval Station antenna having a height of 146 meters.

Antenna L is an antenna having an extended network 10 meters high and of such an area that it radiates at the same rate as the Darien antenna when operated at the same voltage and frequency. It may be called the 10-meter Darien-equivalent antenna.

Antenna S has an extended network 10 meters high but of 1/20 the area of the 10-meter Darien-equivalent network.

Assume that these three antennas are all made resonant to the same frequency, and are used to receive undamped waves of the same intensity. Let the ratio of the wasteful resistance R_w of the antenna plus its radiation resistance R_r to the radiation resistance

be represented by k. Assume that the detector resistance R_d is made equal to the sum of the wasteful resistance plus the radiation resistance, or is made equal to $k R_r$, thus making the total resistance R_t equal to $2 k R_r$.

$$k \text{ represents } \frac{R_w + R_r}{R_r} \tag{1}$$

$$\left.\begin{array}{l} R_d \text{ assumed equal to } R_w + R_r = k R_r \\ \text{then } R_t = R_w + R_r + R_d = 2 k R_r \end{array}\right\} \tag{2}$$

If the height of the high antenna is (n) times as great as that of the low antenna, and if the area of the large network is (s) times as great as the area of the small, then the constants of the three antennas to the resonant frequency are related in the manner shown in Table II.

TABLE II
RELATIVE CONSTANTS OF HIGH, LOW, AND SMALL ANTENNAS TO THE RESONANT FREQUENCY

Antenna	H	L	S
Height of antenna	$n h_0$	h_0	h_0
Area of antenna	$S a_0$	$S a_0$	a_0
Induced voltage	E_0	E_0 / n	E_0 / n
Capacity	C_0	$n C_0$	$n C_0 / s$
Inductance	L_0	L_0 / n	$s L_0 / n$
Radiation resistance	R_0	R_0 / n^2	R_0 / n^2
Final current	$\frac{E_0}{2 k R_0}$	$\frac{n E_0}{2 k R_0}$	$\frac{n E_0}{2 k R_0}$
Final condenser voltage	$\frac{E_0}{2 k R_0 C \omega}$	$\frac{E_0}{2 k R_0 C \omega}$	$\frac{s E_0}{2 k R_0 C \omega}$
Final stored energy $1/2 L I^2$	$\frac{L_0 E_0^2}{8 k^2 R_0^2}$	$\frac{n L_0 E_0^2}{8 k^2 R_0^2}$	$\frac{s n L_0 E_0^2}{8 k^2 R_0^2}$
Final power to detector ($I^2 R_d$)	$\frac{E_0^2}{4 k R_0}$	$\frac{E_0^2}{4 k R_0}$	$\frac{E_0^2}{4 k R_0}$
Time constant (seconds)	$\frac{L_0}{k R_0}$	$\frac{n L_0}{k R_0}$	$\frac{s n L_0}{k R_0}$

R_d assumed equal to $R_w + R_r = k R_r$

The numerical values of the constants of these three antennas are given in Table III for the following frequencies:

1. A frequency equal to the resonant frequency of the antenna. The resonant frequency is taken as 120,000 cycles per second, corresponding to a wave length of 2500 meters.
2. A frequency 1 per cent higher or lower than the resonant frequency; such a frequency cannot always be advantageously eliminated by heterodyne methods.
3. A frequency which is an octave higher or lower than the resonant frequency. Interferent waves of such a frequency would only be troublesome if from a near-by station.

This table also contains data similar to the above for the case in which the antennas are tuned to be resonant to 30,000 cycles, corresponding to a wave length of 10,000 meters. The table shows also the relative *steady-state* power expenditures in the detectors which result from impinging waves of the same intensity and of the above frequencies. In the lines showing the power expenditure, P_0 and P_1 represent the steady-state power expenditure caused by impinging waves of the resonant frequency in the Darien antenna for the hypothetical case in which the wasteful resistance R_w is negligibly small in comparison with the radiation resistance R_r.

6. *The selective coefficient of a receiving circuit.* Let the steady-state *selective coefficient* S_c of a receiving circuit *against* a specified detuned frequency be defined to mean the ratio between the power delivered to the detector by waves of a frequency such as to make the circuit resonant and the power delivered to the same detector by waves *of the same intensity* but of the specified detuned frequency; the power being determined after the current builds up to the steady-state value. A high selective coefficient against detuned frequencies is highly desirable in radio receiving circuits.

The numerical values of the selective coefficients of the high, low and small antennas to the detuned frequencies specified in Table III are the appropriate ratios of the numbers appearing in the lines entitled "Power expended in the detector." From this table it will be seen that the high selective coefficients are to be obtained by using receiving antennas of small area and low height at low frequencies. It should be noted, however, that to obtain this continued increase of the selective coefficient with the decrease in the dimensions of the antenna and in the operating frequency, the wasteful resistances of the antennas must be kept proportional to the radiation resistance; that is, the wasteful resistances must be made smaller and smaller as the antenna dimensions and the operating frequency are decreased.

7. *Relations between the selective coefficient and the antenna dimensions and operating frequency.* The relations between the value of selective coefficient and antenna dimensions and operating frequency may be readily deduced by tabulating the antenna constants in the sequence shown in Table IV. The relations brought out in Table IV may be summarized thus.

The selective coefficient of a highly *oscillatory* antenna against a frequency which is detuned by a small decimal part (p_d) of the resonant frequency f_r varies:

a. inversely as the square of the antenna height.

b. inversely as the square of the area of the antenna network.

c. inversely as the sixth power of the resonant frequency

d. directly as the square of the decimal part (p_d) by which the interferent frequency is detuned.

e. directly as the square of the utilization efficiency ($1/k$) of the antenna.

$$S_c \text{ varies as } \frac{P_d^2}{a^2\, h^2\, k^2\, f_r^6}$$

This expression may also be derived by the following arguments. In any *highly oscillatory* circuit, the impedance Z to an electromotive force which is detuned by a small decimal part p_d of the resonant frequency, is substantially equal to the net reactance to the dissonant frequency or

On the other hand, the power expended by the resonant electromotive force E in the detector of resistance $k\, R_r$ connected in an antenna having an additional antenna resistance of $k\, R_r$, is,—

$$P_2 = \frac{E^2}{4\, k\, R_r}$$

Therefore the selective coefficient S_c of any highly oscillatory circuit is,

TABLE III

CONSTANTS OF HIGH, LOW, AND SMALL ANTENNAS

	Darien antenna	10-meter Darien equivalent	10-meter 5 per cent area	Darien antenna	10-meter Darien equivalent	10-meter 5 per cent area
Constants to a resonant frequency of	120,000 cycles (2500 m)			30,000 cycles (10,000 m)		
Height meters	146.	10.	10.	146.	10.	10.
Area sq. meters		165,000	8,250		165,000	8,250
Capacity μ farads	0.01	0.146	0.0073	0.01	0.146	0.0073
Inductance μ henrys	176.	12.1	242.	2820.	193.	3860.
Inductive or Capacity } reactance ohms	132.	9.08	182.	530.	36.3	726.
Critical resistance ohms	265.	18.16	363.	1060.	72.6	1452.
Radiation " "	5.37	0.0252	0.0252	0.336	0.00158	0.00158
Time constant seconds	0.000032/k	0.00048/k	0.0094/k	0.0084/k	0.112/k	2.44/k
" " periods	3.94/k	57/k	1140/k	252/k	3660/k	73200/k
Resistance ratio R_e/R_t	24.6/k	360/k	7200/k	1580/k	23000/k	460,000/k
Power expended in detector	P_0/k	P_0/k	P_0/k	P_1/k	P_1/k	P_1/k
Constants to a frequency 1 per cent high or low						
Net reactance ohms	2.64	0.182	3.64	10.6	0.73	14.5
Total resistance "	10.7k	0.05 k	0.05 k	0.67 k	0.0032 k	0.0032 k
Impedance "	21.6*	0.208*	3.64	11.4*	0.73	14.5
Power expended in detector	0.98 P_0/k*	0.23 P_0/k*	0.00019 k P_0	0.0034 k P_1*	1.9 × 10^{-5} k P_1	4.7 10^{-5} k P_1
Constants to a frequency an octave high or low						
Net reactance ohms	198.	13.6	273.	797.	54.2	1090.
Total resistance "	10.7 k	0.05 k	0.05 k	0 67 k	0.0032 k	0.0032 k
Impedance "	198.	13 6	273	797.	54.2	1090.
Power expended in detector	2.9 × 10^{-1} k P_0	1.35 10^{-5} k P_0	3.4 10^{-8} k P_0	7.0 10^{-7} k P_1	3.5 10^{-4} k P_1	8.2 10^{-12} k P_1

P_0 and P_1 represent the power expended in the detector when R_w is zero.

*These figures are correct only for the case in which $k = 2$

$R_d = R_w + R_r = k\, R_r$.

$$Z\ (= X_L - X_c) = 2\, p_d\, X$$

in which, X is the reactance of the circuit inductance (or of the condenser) to the resonant frequency f_r.

Therefore the current I which results from the dissonant electromotive force E is

$$I = \frac{E}{2\, p_d\, X}$$

and the power expended in the detector of resistance $k\, R_r$ by the dissonant electromotive force is

$$P_1 = \frac{E^2\, k\, R_r}{4\, p_d^2\, X^2}$$

$$S_c \left(= \frac{P_2}{P_1} \right) = \left(\frac{p_d\, X}{k\, R_r} \right)^2 \qquad (3)$$

Since the critical resistance R_c of a highly oscillatory circuit is equal to twice the reactance of its inductance (or of its condenser) to the resonant frequency, equation (3) for the selective coefficient may be written in the following form:

$$S_c = \left(\frac{p_d\, R_c}{2\, k\, R_r} \right)^2 \qquad (4)$$

Now the radiation resistance and capacity reactance

of an extended antenna network are given approximately by the following expressions:

$$R_r = \frac{160\,\pi^2 f^2 h^2}{s^2}$$

$$X = \frac{1}{2\,\pi f C} = \frac{1}{2\,\pi f}\ \frac{h}{p_0\,A}$$

in which,

h represents the height of the network in cm.

a represents the area of the network in sq. cm.

p_0 represents the permittivity of air, $= 8.84\ 10^{-14}$

s represents the velocity of light, $= 3.10^{10}$ cm. per sec.

Therefore the equation for the selective coefficient (equation 3) may be written,

$$S_c = \frac{p_d^2}{k^2}\left(\frac{h}{2\,\pi f\,p_0\,a}\right)^2\left(\frac{s^2}{160\,\pi^2 f^2 h^2}\right)^2$$

$$S_c = \frac{9\,p_d^2\,s^6}{64\,\pi^4\,k^2\,h^2\,a^2\,f_r^6} \qquad (5)$$

We proceed to examine the limits within which the equations for the *steady-state* selective coefficient of a circuit will represent the selective properties of the circuit when the electromotive force is impressed, not for an unlimited time, but for a Morse dot interval only.

8. *Relation between the selective coefficient and the time constant of a circuit.* The expression for the time constant T_c of a series antenna circuit may be written in the forms:

$$T_c = \frac{2\,L}{2\,k\,R_r}\ \text{seconds}$$

$$T_c = \frac{3\,s^3}{16\,\pi^3\,k\,a\,h\,f_r^4}\ \text{seconds} \qquad (6)$$

On comparing these expressions for the time constant with equations **3**, **4** and **5** for the selective coefficient, it is seen that the expressions for the steady-state selective coefficient may be written in the following forms:

$$S_c = (2\,\pi\,f_r\,p_d\,T_c)^2 \qquad (7)$$

$$S_c = (2\,\pi\,c_d\,T_c)^2 \qquad (7a)$$

in which

c_d represents the number of cycles per second by which the interferent source is detuned.

TABLE IV

EFFECT OF THE ANTENNA HEIGHT AND AREA AND THE RESONANT FREQUENCY UPON THE SELECTIVE COEFFICIENT OF HIGHLY OSCILLATORY RECEIVING ANTENNAS

The table is based upon the assumption that the net reactance of the circuit to the detuned frequency greatly exceeds the ohmic resistance of the circuit.

	Effect of height		Effect of area		Effect of resonant frequency	
Height	h	$n\,h$	h	h	h	h
Area	a	a	a	$s\,a$	a	a
Frequency	f	f	f	f	f	$b\,f$
Induced voltage	E	$n\,E$	E	E	E	E
Capacity or Inductive reactance	X	$n\,X$	X	X/s	X	X/b
Net reactance under p_d decimal parts detuning	$2\,p_d\,X$	$n\,2\,p_d\,X$	$2\,p_d\,X$	$2\,p_d\,X/s$	$2\,p_d\,X$	$2\,p_d\,X/b$
Total circuit resistance	$2\,k\,R$	$2\,k\,n^2\,R$	$2\,k\,R$	$2\,k\,R$	$2\,k\,R$	$2\,k\,b^2\,R$
Current at detuned frequency	$\frac{E}{2\,p_d\,X}$	$\frac{E}{2p_d\,X}$	$\frac{E}{2\,p_d\,X}$	$\frac{s\,E}{2\,p_d\,X}$	$\frac{E}{2\,p_d\,X}$	$\frac{b\,E}{2\,p_d\,X}$
Current at resonant frequency	$\frac{E}{2\,k\,R}$	$\frac{E}{2\,k\,n\,R}$	$\frac{E}{2\,k\,R}$	$\frac{E}{2\,k\,R}$	$\frac{E}{2\,k\,R}$	$\frac{E}{2\,k\,b^2\,R}$
Power to detector at detuned frequency	$\frac{E^2\,k\,R}{4\,p_d^2\,X^2}$	$\frac{E^2\,k\,n^2\,R}{4p_d^2\,X^2}$	$\frac{E^2\,k\,R}{4\,p_d^2\,X^2}$	$\frac{s^2\,E^2\,k\,R}{4\,p_d^2\,X^2}$	$\frac{E^2\,k\,R}{4\,p_d^2\,X^2}$	$\frac{E^2\,b^4\,k\,R}{4\,p_d^2\,X^2}$
Power to detector at resonant frequency	$\frac{E^2}{4\,k\,R}$	$\frac{E^2}{4\,k\,R}$	$\frac{E^2}{4\,k\,R}$	$\frac{E^2}{4\,k\,R}$	$\frac{E^2}{4\,k\,R}$	$\frac{E^2}{4\,k\,R}$
Power at resonant frequency / Power at detuned frequency	$\frac{p_d^2\,X^2}{k\,R_1^2}$	$\frac{n^2\,p_d^2\,X^2}{k^2\,R^2}$	$\frac{p_d^2\,X^2}{k^2\,R^2}$	$\frac{s^2\,p_d^2\,X^2}{k^2\,R^2}$	$\frac{p_d^2\,X^2}{k^2\,R^2}$	$\frac{b^4\,p_d^2\,X^2}{k^2\,R^2}$

NOTE: In each antenna the antenna resistance ($R_w + R_r$) is assumed to be equal to k times the radiation resistance R_r and the detector resistance is assumed equal to $k\,R_r$.

In other words, an extremely high selective coefficient is to be obtained only by using a long time constant. Now if the time constant of the circuit is made so long that in the interval T_e during which the voltage is impressed (the Morse dot interval in sustained wave reception, and the length of the wave train in spark systems), the current has time to build up to only a small fractional part of its steady-state value, then the energy which is delivered to the detector by the resonant voltage is only a small fractional part of the energy which would be delivered to the detector in an equal interval of time after the steady-state is attained. On the other hand, the initial rate (the rate during the first beat) at which energy is delivered to the detector by the detuned electromotive force is approximately equal to twice the rate at which energy is delivered to the detector by the steady-state detuned current. (See Fig. 5.)

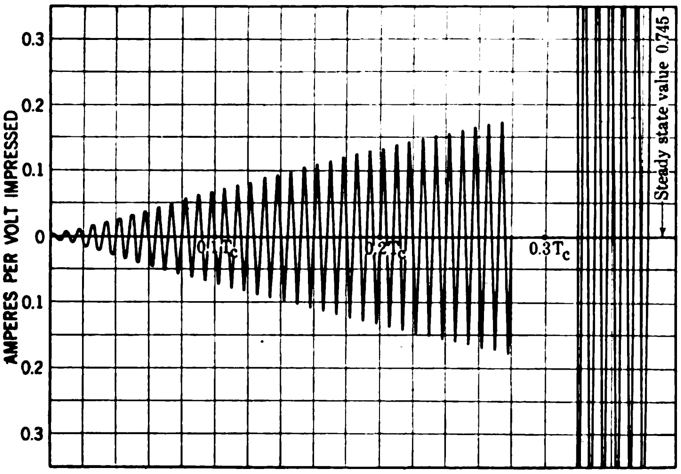

FIG. 4—RISE OF CURRENT IN DARIEN ANTENNA

Impressed frequency = resonant frequency
$R_t = 4\ R_r = 1.34$ ohms
R_c = 1060 ohms
$T_c = 0.0042$ sec. = 126 periods
$E/R = 0.745\ E$

As an illustration of this discussion, the curves showing the manner in which the current builds up in the ten meter Darien-equivalent antenna under resonant and under detuned electromotive forces have been plotted in Figs. 4 and 5. In Fig. 4 the circuit is resonant to the impressed frequency (30,000 cycles), and in Fig. 5 the impressed frequency is 8 per cent higher or lower than the resonant frequency. The circuit constants for these curves are to be found in column 7 of Table III.

Let the time interval during which the electromotive force is impressed in the (antenna) circuit be called the *time interval of excitation*, T_e. In sustained wave systems, the time interval of excitation is the Morse dot interval, (0.05 second at a speed of thirty words per minute). In spark systems, the interval of excitation may be said to be the effective length, (which we do not at present attempt to define) of the wave train. An inspection of Figs. 4 and 5 indicates that if the time constant of an antenna is longer than one tenth of the interval of excitation, the expressions for the selective coefficient (equations 3, 4, 5 and 6) which have been derived for the steady-state conditions fail to represent the relative amounts of energy delivered to the detector at the detuned and resonant frequencies.

We are now in a position to correct an erroneous conclusion to which equation (**5**) is likely to lead.

$$S_c = \frac{9\ p_d^2\ s^6}{64\ \pi^4\ k^2\ a^2\ h^2\ f_r^6} \tag{5}$$

This expression for the selective coefficient would indicate that to obtain a high selective coefficient the operating frequency should be low and the dimensions of the antenna small. While this conclusion would be correct for a radio transmission system operating with an uninterrupted flow of power, it is grossly erroneous for a make and break communication system. In a dot and dash communication system it is not permissible to decrease the dimensions and the frequency indefinitely; because with this decrease, the time constant of the circuit increases, and a condition may very readily be reached in which the time constant of the circuit far exceeds the Morse dot interval. Under this condition, the current at the resonant frequency has only time to build up to a small fractional part of the full or steady-state value, and equation (**5**) fails to express the *Morse-dot-interval-*selective-coefficient. Accordingly, the conclusions drawn from equation (**5**) should be discarded; the steady state selective coefficient should be expressed in terms of the resonant frequency and the time constant, as in equation (**7**), and the indications of this equation followed. This equation indicates that to obtain a high selective coefficient, the resonant frequency should be high and the time constant as long as possible, subject to the limitations which we proceed to develop in Sections 8, 9 and 16.

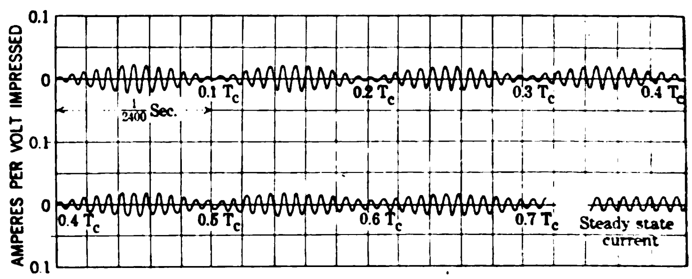

FIG. 5—RISE OF CURRENT IN DARIEN ANTENNA

Impressed frequency = $(1 + 0.08)$ resonant frequency
Resonant frequency = 30,000
$R_t = 4\ R_r = 1.34$ ohms
R_c = 1060 ohms
X = 84.6 ohms
Beats per sec. = 2400
$T_c = 0.0042$ sec. = 126 periods = 10 beats
$E/Z = 0.0118\ E$

9. *The Limit Placed on the Time Constant by the Necessity for Intervals of Silence.* The following consideration precludes the use, in a sustained wave system, of a receiving circuit whose time constant is much longer than 0.2 of the Morse *space interval.* The oscillating current in the receiving antenna circuit does not cease at the end of the Morse dot interval when the induced voltage ceases, but, because of the energy which has been stored, the current continues to flow with gradually diminishing amplitude. At the end of the space between the dots and dashes, the oscillatory current is not necessarily zero; but if the time constant of the receiving circuit is equal to the Morse space interval, the current is still equal to 36.8 per cent of its value at the end of the previous dot or dash. That is, if the time constant of the circuit is as long as the Morse space interval, the current in the receiving circuit would never cease but would fluctuate over a range of about 2.7 to 1. Under these conditions, the supply of power to the detector would fluctuate in the ratio of 7.3 to 1, and the note in the telephone would not be a series of dots and dashes but a continuous note of varying intensity. Let us assume that to provide for an interval of silence during the space between Morse dots and dashes, the time constant of the receiving circuit should be so short that the current in the receiving circuit will die down to one per cent of its initial value. This is equivalent to saying that the length of the Morse space interval should be 4.6 times as great as the time constant of the circuit, or that the time constant should not exceed 21.6 per cent of the Morse space interval. Since the Morse dot and Morse space intervals are equal, the time constant of the receiving circuit in sustained wave systems should not exceed 0.2 of the interval of excitation — the Morse dot interval. As the space or the dot interval at thirty words per minute is 0.05 second, the time constant of the receiving circuit should not exceed 0.01 second.

Since in a spark system it is not necessary to provide for intervals of silence (zero energy delivery) between sparks, but simply to make the time constant so short that the energy received from each wave train is delivered to the telephone receiver in distinct pulses, it is not necessary to reduce the time constant to 0.2 of the interval between periods of excitation. The time constant may be allowed to equal 40 per cent of the time interval between wave trains. In rapidly damped spark systems, the space interval between wave trains may equal 90 per cent or more of the interval between sparks. Under these conditions the time constant of the circuit should not exceed 0.4 of the interval between sparks, or at 1000 sparks per second should not exceed 0.0004 second. In such a rapidly damped spark system, *if* the effective length of the wave train is 0.1 of the interval between sparks, it follows that the time constant of the circuit may be four times as long as the interval of excitation.

10. *The Selective Coefficient for the Interval of Excitation.* Let the *selective coefficient* (of an antenna circuit) *for the interval of excitation,* T_e, against a specified detuned frequency be defined to signify the ratio between the energy delivered to the detector by an impressed alternating electromotive force of a frequency such as to make the circuit resonant and the energy delivered to the same detector by an impressed electromotive force of the same value but of the detuned frequency, both electromotive forces being impressed for the same interval of time, T_e.

Perhaps the most satisfactory method of determining the conditions under which, and the extent to which, the selective coefficient as above defined differs from the steady-state selective coefficient, is to plot the curves which will show the effect of the length of the circuit time constant upon the ratio between the energy delivered to the circuits by an electromotive force impressed for an interval T_e and the energy which would be expended in the circuits in the interval of time T_e by the steady-state current corresponding to the impressed electromotive force. Ratio curves of this kind have been plotted in Fig. 6, using as abscissas the ratios of the time constants of the circuits to the time interval of excitation. All of these curves are plotted for the case in which an alternating electromotive force of constant value is impressed for a definite interval T_e in a circuit which is resonant to the impressed frequency. At the end of the interval T_e, the impressed electromotive force ceases and the oscillation, which has been building up, then dies down as the energy stored in the circuit during the interval T_e is gradually dissipated. If the detector resistance is proportioned as in equation (2), one half of the total energy delivered to the antenna circuit is delivered to the detector and the other half is partly expended in the wasteful resistance and partly re-radiated.

In Fig. 6, curve A shows the ratio between the value which the current has attained at the end of the interval of excitation T_e and the ultimate or steady-state value of the current under the same electromotive force if long sustained. Curve B shows the ratio between the power expenditure in the circuit resistance at the end of the interval T_e and the power expenditure which would occur in the resistance under the steady-state current. For example, if the time constant of the circuit is equal to 0.2 of the interval of excitation, the current at the end of the interval of excitation has attained 0.993 of the steady-state value and the power expenditure in the resistance and hence the power delivery to the detector has attained to 0.986 of the steady-state value. The equation of curve A is

$$i/I = 1 - \epsilon^{-T_e/T_c} \tag{8}$$

Curve C shows the ratio of the energy actually expended in the circuit resistance in the interval T_e,

while the electromotive force is still impressed in the circuit, to the energy which would be expended in the interval T_e by the steady-state current corresponding to the impressed electromotive force. The equation of this curve is,—

$$\frac{\int_0^{T_e} i^2 R\, d t}{I^2 R T_e} = 1 - \frac{1.5\, T_c}{T_e} + \frac{2\, T_c}{T_e}\, \epsilon^{-T_e/T_c} - \frac{T_c}{2\, T_e}\, \epsilon^{-2T_e/T_c} \quad (9)$$

$$= 1 - \frac{1.5\, T_c}{T_e} \quad \text{if } \frac{T_c}{T_e} < 0.5 \quad (9a)$$

$$= \frac{1}{3}\left(\frac{T_e}{T_c}\right)^2 \quad \text{if } \frac{T_c}{T_e} > 5. \quad (9b)$$

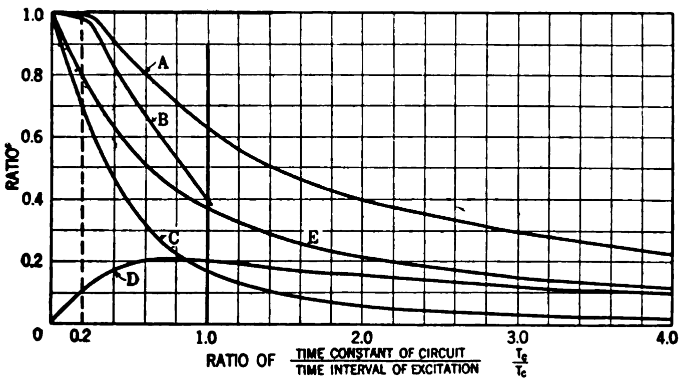

FIG. 6—CURRENT AND ENERGY RATIOS IN A RESONANT CIRCUIT

T_e represents interval of excitation

I " value of steady state current

A shows $\frac{\text{current at end of } T_e}{I}$

B " $\frac{i^2 R \text{ at end of } T_e}{I^2 R}$

C " $\frac{\int_0^{T_e} i^2 R\, d t}{I^2 R T_e}$

D " $\frac{\text{Energy stored at end of } T_e}{I^2 R T_e}$

E " $\frac{\text{Total energy delivered during } T_e}{I^2 R T_e}$

Curve D shows the ratio between the energy *stored* in the circuit at the end of the interval T_e, at which instant the impressed electromotive force ceases, and the energy which would have been expended in the circuit in the interval T_e, by the steady-state current. The equation of this curve is,—

$$\frac{\text{Energy, stored at end of } T_e}{I^2 R T_e} = \frac{T_c}{2\, T_e} \cdot (1 - 2\, \epsilon^{-T_e/T_c} + \epsilon^{-2T_e/T_c}) \quad (10)$$

$$= \frac{T_c}{2\, T_e} \quad \text{if } \frac{T_c}{T_e} < 0.2 \quad (10a)$$

$$= \frac{T_e}{2\, T_c}\left(1 - \frac{T_e}{T_c}\right) \quad \text{if } \frac{T_c}{T_e} > 5 \quad (10b)$$

The total energy which will eventually be expended in the resistances of the circuit as the result of the impressing of the resonant electromotive force for the interval T_e is the sum of the energy expended in the circuit resistances during the interval T_e (as shown by Curve C) and the energy stored at the end of the interval T_e (as shown by curve D). Curve E shows the ratio of this sum to the energy which would have been expended in the interval T_e by the steady-state current. The equation of Curve E is,—

$$\frac{\text{Total energy delivered to circuit}}{I^2 R T_e} = 1 + \frac{T_c}{T_e}\, (\epsilon^{-T_e/T_c} - 1) \quad (11)$$

$$= 1 - \frac{T_c}{T_e} \quad \text{if } \frac{T_c}{T_e} < 0.2 \quad (11a)$$

$$= \frac{T_e}{2\, T_c}\left(1 - \frac{1}{3}\, \frac{T_e}{T_c}\right) \quad \text{if } \frac{T_c}{T_e} > 5 \quad (11b)$$

The ratio of the total energy delivered to the circuit by a *slightly detuned* electromotive force which is impressed for a time interval T_e which is short in comparison with the time constant of the circuit, to the energy which would be *expended* in the circuit in the interval T_e by the steady-state detuned current varies greatly with the point at which the impressed voltage ceases. (See Fig. 5.) For example, if the detuned voltage is interrupted at the first current node, the ratio of the energy delivered to the circuit to the energy which would be expended in the circuit by the steady-state detuned current is substantially 2 to 1. While if the voltage is interrupted at the first antinode of the current and if the time constant is long in comparison with the interval of excitation, the ratio becomes substantially $\left(2 + \frac{2\, T_c}{T_e}\right)$ to 1.

Hence, we may draw the following conclusions relative to the energy delivered to a circuit by a detuned voltage which is impressed for an interval T_e. First: If the time constant of the circuit is less than 0.2 of the interval of excitation, the ratio between the total energy delivered to the circuit by the detuned electromotive force and the energy which would be expended in the circuit in the interval T_e by the steady-state detuned current corresponding to the detuned voltage may be taken as roughly 1 to 1. Second: If $T_c > 5\, T_e$, the ratio will lie between 2 and

$\left(2 + \frac{2\,T_c}{T_e}\right)$ to 1, depending on the point of the beat at which the impressed voltage ceases. For the unfavorable cases the ratio may be written as roughly

$$\frac{2\,T_c}{T_e}.$$

From the data in the above paragraph and that to be obtained from Curve E of Fig. 6, we may now draw conclusions as to the conditions under which, and the extent to which, the selective coefficient for the interval of excitation will differ from the steady-state-selective-coefficient. If the time constant of the circuit is less than one tenth of the interval of excitation, the selective coefficient for the interval of excitation may be taken as approximately equal to the steady-state-selective-coefficient. An inspection of Fig. 5 and Curve E of Fig. 6 shows that if the time constant of the circuit has the greatest length allowable in sustained wave systems, namely a length equal to 0.2 of the interval of excitation, the excitation-interval-selective-coefficient will be somewhat less than 0.8 of the steady-state-selective-coefficient. If the time constant of the circuit were increased until it equaled in length the interval of excitation, the excitation-interval-selective-coefficient would not exceed 0.2 of the steady-state-selective-coefficient. That is, while an increase in the time constant from $0.2\,T_e$ to T_e, or an increase of 5 to 1 in the time constant, will increase the steady-state-selective-co-efficient in the ratio of 25 to 1, it increases the excitation-interval-selective-coefficient in the ratio of less than 5 to 1.

After the time constant of the circuit has been made as long as the interval of excitation, a further increase in the length of the time constant produces only a moderate increase in the value of the excitation-interval-selective-coefficient. If the time constant is 5 or more times as long as the interval of excitation, the excitation-interval-selective-coefficient is equal to $1/4\,(T_e/T_c)^2$ of the steady-state-selective-coefficient.

$$S_c = \frac{1}{4}\left(\frac{T_e}{T_c}\right)^2 (2\,\pi\,f_r\,P_d\,T_c)^2 \text{ if } T_c > 5\,T_e$$

$$S_c = \frac{1}{4}\,(2\,\pi\,f_r\,P_d\,T_e)^2 \qquad \text{if } T_c > 5\,T_e \quad \textbf{(12)}$$

The conclusions are:

In sustained wave systems the time constant should not be longer than 0.2 of the interval of excitation.

If $T_c = .2\,T_e$

Excitation-interval

$$S_c = 0.8 \text{ (Steady-state } S_c\text{) roughly}$$
$$= 0.8\,(2\,\pi\,f_r\,p_d\,T_c)^2 \quad \text{“} \quad \textbf{(13)}$$
$$= 0.032\,(2\,\pi\,f_r\,p_d\,T_e)^2 \quad \text{“} \quad \textbf{(13a)}$$

In rapidly damped spark systems (in which T_c may be greater than $0.2\,T_e$) the excitation-interval-selective-coefficient is only moderately increased by making T_c greater than T_e.

If $T_c = T_e$

Excitation-interval

$$S_c = .2\,(2\,\pi\,f_r\,p_d\,T_c)^2 \text{ roughly} \quad \textbf{(14)}$$
$$= .2\,(2\,\pi\,f_r\,p_d\,T_e)^2 \quad \text{“} \quad \textbf{(14a)}$$

11. *Feasibility of obtaining tuning inductances with time constants of* 0.04 *seconds or longer.* The time constant (defined as equal to L/R) of the average inductance found in electrical laboratories and in radio receiving sets is of the order of 0.0001 to 0.001 second. Accordingly, the question arises as to the feasibility of obtaining special tuning inductances whose resistances will be low enough to permit of making the time constant of the receiving circuit as long as 0.01 seconds.

In considering this question, let us suppose that substantially all of the inductance of the antenna receiving circuit must be provided for in the loading and tuning coil. Suppose further that of the total wasteful resistance, one-half may be allowed in the tuning coil. If the further assumption is made that the total wasteful resistance is not to exceed the radiation resistance, then the time constant of the tuning inductance (defined as L/R) is equal to $L \div 1/2\,R_r = 2\,L/R_r$. But the time constant of the oscillatory circuit itself (defined as $2\,L/R$) is $2\,L \div 4\,R_r = L/2R_r$. Therefore under the assumed conditions, the time constant of the tuning inductance (L/R) must be four times as great as that of the receiving circuit, or the time constant of the tuning coil must be at least 0.04 seconds.

Calculations indicate that it may be feasible to construct tuning inductances having time constants as long as 0.04 second at the lower frequencies (15,000 cycles).

12. *The combination of antenna height and area and resonant frequency which will give the highest selective coefficient for a given time constant.* From equation (7) it is seen that a high selective coefficient may be obtained by using a long time constant and a high frequency. It has been shown that other considerations prohibit the use of a time constant longer than 0.01 second. From equation (6) it is seen that the time constant of 0.01 second may be obtained either at a high or a low frequency. For example, if a given resonant frequency is used in antenna A, and if in antenna N it is desired to use a frequency (n) times as great, for the purpose of obtaining a selective coefficient n^2 times that of A, the time constant of N may be made the same as that of A by making the product of $a \times h$ (area $\times$ height) for antenna N $(1/n)^4$, times as great as the ($a\,h$) product of antenna A. That is, if the time constant is to be retained unchanged, then as the resonant or operating frequency is increased, lower heights or lower areas must be used. If the frequency is doubled, ($a\,h$) must be made 1/16 as great.

It should be noted that while equation (7) is not perfectly general but applies only to highly oscillatory circuits, yet this fact does not set an upper limit to the frequency at which equation (7) may be used. This may be seen from the expression for the ratio of the critical resistance of a circuit to its actual resistance, namely:—

$$\frac{R_c}{R} = 2\,\pi\,f_r\,T_e \qquad (15)$$

That is, if two circuits have the same time constant, the circuit having the higher resonant or natural frequency is the more highly oscillatory circuit.

It follows, then, that the upper limit to the frequency which should be used will be set by considerations other than those arising from the selective properties of the receiving circuit. The limit will be set by considerations such as—the greater attenuation with distance suffered by the higher frequencies, or the difficulty of obtaining satisfactory sustained wave generators for the higher frequencies, or by the smaller power abstracting efficiency of the antennas at the higher frequencies.

From the equations (6) and (7) may be plotted the two curves shown in Fig. 7. Curve ($a\ h$) shows the $a\ h$) product which should be used with any frequency in order to obtain a time constant of .01 sec. The equation of this curve is

$$a\,h = \frac{3\,s^3}{16\,\pi^3\,k\,T_c\,f_r^{\,4}} \qquad (16)$$

Assuming k to equal 2, (or $R_t = R_r + R_w + R_d = 4\,R_r$) and substituting $T_c = .01$, this equation becomes,—

$$a\,h = \frac{8.15\ 10^{30}}{f_r^{\,4}}\ \text{cu. cm.}$$

Curve S_e of Fig. 7 shows the selective coefficient to a frequency detuned by 1 per cent, when the antenna is proportioned to have a time constant of 0.01 second. The equation of the curve is

$$S_e = (2\,\pi\,f_r\,p_d\,T_c)^2 \qquad (7)$$

It should be noted that while the selective coefficient varies directly as the square of the resonant frequency, the power which may be abstracted by two antennas from impinging waves of a given in-

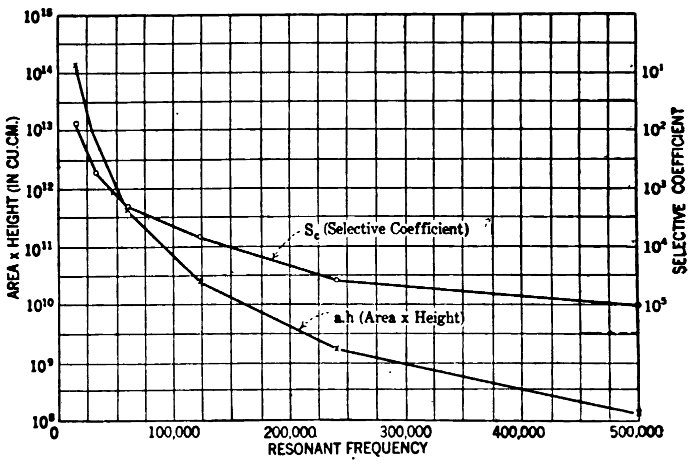

Fig. 7—Resonant Frequency Versus Dimensions and Selective Coefficient of an Extended Antenna Having a Time Constant of 0.01 Second

Interferent station detuned 1 per cent.
Note: The spotted points alone are exact.

tensity but of different frequencies varies inversely as the square of the frequencies. In other words, the effectiveness of a receiving antenna as an abstracter of energy in a power transmission system varies inversely as the square of the frequency or directly as the square of the wave length. The demonstration of this proposition is given in the next section.

(To be Continued)

PORTABLE REFLECTOMETER

Some time ago there was described a new type of reflectometer, suitable for measuring the reflection of light from walls, ceilings and other objects, which had been developed at the Bureau of Standards. Incidentally, measurements made with this instrument showed that there had been serious errors in the values previously accepted for the reflection factors of most materials. The development of this instrument and the publication of the values obtained with it stimulated considerable interest in this subject and a number of somewhat similar reflectometers have since been made up by other experimenters. All of the results obtained have corroborated those obtained at the Bureau of Standards.

The instrument then described depended upon computations which were somewhat complex and considerable precautions were necessary in its use in order to obtain correct values. In order to obviate these difficulties, a different type of instrument has been developed which depends on the same fundamental principles as the original one but is more simple in operation. The new instrument was described before the Convention of the Illuminating Engineering Society last month and the description will be published soon in the transactions of that Society as well as in the scientific papers of the Bureau. The description of the original instrument has already been published as Scientific Paper No. 391 and also in the *Journal of the Optical Society of America*, Volume 4, No. 1, January, 1920.

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A. I E. E. PUBLICATION POLICY

At a conference held October 6 by the Publication and Finance Committees of the Institute certain changes in the Institute's policy regarding the monthly JOURNAL and annual TRANSACTIONS were recommended, as embodied in the following resolutions:

VOTED to recommend to the Board of Directors that commencing with the volume of Institute TRANSACTIONS covering the year 1921, the practice of furnishing a copy of the TRANSACTIONS to each member of the Institute be discontinued, and that copies be furnished to all members who subscribe in advance at a price to be determined later, possibly 5. per year; the edition to be determined by the advance subscriptions received, with a reasonable allowance for stock to meet future demands.

Voted that commencing with the January 1921 meetings of the Institute a resume of the discussion at each meeting be printed in the JOURNAL from month to month, so that members who do not obtain the TRANSACTIONS will have this discussion in their JOURNAL.

These recommendations were considered by the Board of Directors at its meeting held in Philadelphia, October 8, at which time the recommendations were approved in principle and the Board directed that a statement regarding the matter be published for the information of the membership.

The purpose of the proposed change is the elimination of the enormous waste, which has been discussed by Institute members for the past twenty years, caused by the duplication of expense in printing twice, practically all the papers presented at Institute meetings, once in the monthly JOURNAL and again in the annual TRANSACTIONS and furnishing copies of both publications to all members.

The immediate occasion for the action may be traced directly to the great increase in the cost of carrying on the various Institute activities, particularly the increased costs of paper, printing, and binding, which have increased more than 100 per cent in five years. For example, the annual TRANSACTIONS for the year 1916 actually cost $1.92 per copy, whereas a close estimate of the cost of printing the 1920 TRANSACTIONS is $3.89 per copy; the amount of material being practically the same in both volumes, and the 1920 edition being considerably increased over the 1916, which ordinarily would result in a decrease in the cost per copy instead of an increase of 103 per cent.

The cost of carrying on practically all the other activities of the Institute has also increased, although not to the same degree as indicated above. It is obvious, therefore, that it is impossible to continue the Institute activities on the old basis without an increase in revenue. The two committees referred to and the Board of Directors have therefore decided that instead of recommending an immediate increase in dues or a decrease in activities, that the policy which is in effect in many other technical societies of making an additional charge for the annual bound volume to be established; thus in effect increasing the dues, but only for those members who desire the annual TRANSACTIONS in addition to the monthly JOURNAL.

It will be noted that the change will not apply to the 1919 and 1920 TRANSACTIONS. The former volume has been unavoidably delayed due to the congestion in the printing industry since the strike which began in the Fall of 1919. It has now been completed, however, and distribution was commenced early in October and will be completed during the early part of November. The 1920 volume will also be delayed as the available funds are not sufficient to provide for the completion of the volume in the immediate future.

A. I. E. E. MEETING IN CHICAGO

On Friday, November 12, 1920, the American Institute of Electrical Engineers will hold its 365th meeting under the auspices, jointly, of the Chicago Section and the Protective Devices Committee. The Electrical Section of the Western Society of Engineers will participate.

The technical session at which four papers will be presented on the subject of "Lightning Protection," will be held at 7:30 p. m. at City Club, 315 Plymouth Court. This session will be preceded by an informal reception at 5:15 p. m. and an informal dinner ($2.50 per plate), also at the Club rooms, at 5:45 p. m. The rooms of the Western Society of Engineers, 1735 Monadnock Block, have been designated as Institute headquarters and the Board of Directors and various scheduled committees will hold their meetings there during the afternoon.

PROGRAM

3:00 p. m.—Board of Directors, Western Society of Engineers' Rooms, 1735 Monadnock Block.
5:15 p. m.—Informal Reception, City Club, 315 Plymouth Court.
5:45 p. m.—Dinner, City Club.
7:30 p. m.—Technical Session, City Club,

1. Lightning Arrester Spark Gaps—II. By C. T. Allcutt, of the Westinghouse Electric & Mfg. C.
2. Life and Performance Tests of *O F* Lightning Arresters. By N. A. Lougee, of the General Electric Co.
3. Studies in Lightning Protection on 4000-Volt Circuits—II. By D. W. Roper, of the Commonwealth Edison Co.
4. Electrostatic Condensers. By V. E. Goodwin, of the General Electric Co.

FUTURE A. I. E. E. MEETINGS

At its meeting in Philadelphia, October 8th, the meetings and Papers Committee arranged for this season's Institute meetings as follows:

November Meeting, Chicago.
January Meeting, Cleveland.
February, Midwinter Convention, New York.
March Meeting, New York.
April Meeting, Pittsburgh.
May, Annual Meeting, New York.
June, Annual Convention, Salt Lake City.

THE PHILADELPHIA MEETING

The 364th meeting of the A. I. E. E. was held in Philadelphia, Pa., October 8, 1920, at the Bellevue-Stratford Hotel. The registered attendance was 198. The meeting consisted of a technical session in the afternoon and a celebration of the centenary of the discoveries of Oersted, Ampere, Arago and Davy in the evening. An informal dinner was served in the ballroom of the hotel at 6 p. m., after which President Berresford made a brief address in regard to the policies and activities of the Institute.

Technical Session

The afternoon session was called to order by President Berresford, and the first paper, *Economic Study of Secondary Distribution*, by P. O. Reyneau and H. R. Seelye, was abstracted by Mr. Reyneau. This was followed by the presentation of the paper, *Electrical Demand Measurements*, by P. A. Borden, which was read by the author.

A discussion of the two papers followed which was participated in by W. I. Slichter, D. W. Roper, Paul M. Lincoln, C. I. Hall and W. H. Pratt, with closure by the authors.

Evening Session

The evening session was devoted to the celebration of the early electrical discoveries, of Ampere, Arago, Davy and Oersted, the speakers being Dr. Elihu Thomson and Dr. M. I. Pupin. These addresses will be published in an early issue of the Journal. Replicas of the apparatus used by the pioneer discoverers were prepared and demonstrated by Prof. Harold Pender during the session.

A. I. E. E. DIRECTORS' MEETING
OCTOBER 8, 1920

The regular monthly meeting of the Board of Directers of the American Institute of Electrical Engineers was held at the Bellevue-Stratford Hotel, Philadelphia, on Friday, October 8, 1920, at 10:30 a. m.

There were present: President A. W. Berresford, Milwaukee; Past President C. A. Adams, New York; Vice-Presidents, Charles S. Ruffner, New York, L. T. Robinson, Schenectady, E. H. Martindale, Cleveland; Managers W. A. Hall, Atlantic, Mass.. W. A. Del Mar, W. I. Slichter, E. B. Craft, New York, F. D. Newbury, Pittsburgh, H. B. Smith, Worcester, J. F. Lincoln, Cleveland; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

A report was presented of a meeting of the Board of Examiners held September 27, 1920; and the actions taken on applications at that meeting were approved. Upon recommendation of the Board of Examiners the following action was taken upon pending applications: 22 Students were ordered enrolled; 157 applicants were elected to the grade of Associate; 10 applicants were elected to the grade of Member; 3 applicants elected to the grade of Fellow; 37 applicants were transferred to the grade of member; 3 applicants were transferred to the grade of Fellow.

The action of the Finance Committee in approving monthly bills amounting to $16,153.03 was confirmed.

Upon recommendation of the Finance Committee, a budget covering the activities of the Institute for the appropriation year commencing October 1, 1920, was approved.

The Meetings and Papers Committee reported upon plans in progress for the following meetings: Chicago, November 12; Cleveland, January (date to be decided later); New York, Midwinter Convention, February 23-25; New York, March 11; Pittsburgh, April 8.

Mr. Bancroft Gherardi was appointed to succeed the late Dr. Samuel Sheldon as one of the Institute's representatives on the Board of Trustees of the United Engineering Society.

The following committee appointments made by the President were announced: Law Committee—H. H. Barnes, Jr., Chairman, succeeding Dr. Sheldon; Special Committee on Geographical Divisions and Election Procedure—F. L. Hutchinson, succeeding Dr. Sheldon; Library Committee—W. I. Slichter, to succeed Dr. Sheldon as Chairman, and E. B. Craft as member.

The Committee on Geographical Divisions and Election Procedure presented a progress report, outlining tentatively a division of the membership into ten geographical districts and transmitting suggested changes in the by-laws.

It was voted to hold the next meeting of the Board of Directors in Chicago on the date of the Institute meeting, Friday, November 12.

The Standards Committee submitted revised standardization rules which the Board directed to be printed and published as "Standards of the American Institute of Electrical Engineers".

A petition from the Utah Section for an extension of territory was granted.

A memorial minute was adopted in recognition of the eminent services of Dr. Samuel Sheldon, Past-President of the Institute, who died in Middlebury, Vermont, September 4, 1920, and whose services to the Institute and the engineering profession generally were outlined in the obituary notice published in the October issue of the Journal.

In addition to these actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matter may be found in this and future issues of the Journal under suitable headings.

MEMORIAL EXERCISES TO DR. SAMUEL SHELDON

Memorial exercises to the late Dr. Samuel Sheldon, Past-President of the Institute, and Professor of Electrical Engineering and Physics at the Polytechnic Institute of Brooklyn, will be held in the Auditorium of the Engineering Societies Building, 33 West 39th Street, New York, on Wednesday evening, November 17, 1920 at 8:30 o'clock. President Arthur W. Berresford will preside and addresses on Dr. Sheldon's life and work will be delivered by his close professional friends. The committee which is planning these exercises is headed by Mr. T. Commerford Martin and includes the following professional associates of Dr. Sheldon: Messrs. Edward D. Adams, Alfred D. Flinn, William N. Dickinson, Bancroft Gherardi, Erich Hausmann, C. O. Mailloux, Calvin W. Rice, Charles A. Terry and Calvert Townley. Representatives of the Corporation, Faculty, Alumni and Students of the Polytechnic Institute are cooperating with the foregoing committee. Ladies are invited.

1921 ANNUAL CONVENTION— SALT LAKE CITY

At a meeting of the Board of Directors of the A. I. E. E. held in Philadelphia, October 8, it was decided to hold the 1921 Annual Convention jointly with the Pacific Coast Convention, at Salt Lake City, Utah, during the week beginning Monday, June 20,

The movement to hold the convention at Salt Lake City started at the Pacific Coast Convention held in Portland, Oregon, July 21-24; at the convention session which was devoted to a discussion of Institute activities a resolution was unanimously adopted requesting the Board of Directors to consider holding the 1921 Annual Convention and the Pacific Coast Convention jointly, in Salt Lake City. Later this action was heartily endorsed by the Utah Section of the Institute and other organizations in Salt Lake City.

The principal argument in favor of combining the two conventions, as advanced at the Portland convention, was the desirability of bringing the eastern and western members of the Institute together occasionally for an interchange of ideas, in-

stead of holding two conventions each year, namely, the Annual in the eastern portion of the country, attended by very few of the far western members, and the Pacific Coast Convention, attended by only a few eastern members. The records show that no Annual Convention of the Institute has ever been held west of Omaha, and none west of the Mississippi River since the St. Louis Convention in 1904.

The Directors also had before them a cordial invitation from the Toronto Section of the Institute to hold the 1921 Annual Convention in the City of Quebec. The locations of the Annual Conventions for the past several years—practically all in the New England and Middle States—strongly supported the argument in favor of a western location for next year's meeting; and while appreciating the fact that the attendance from the members in the East will probably not be great, the Board decided to accede to the wishes of the membership located in the Pacific Coast and Rocky Mountain States as unanimously expressed at the Pacific Coast Convention in Portland, and otherwise by resolutions and other communications.

NATIONAL STANDARDIZING BODY ORGANIZED IN AUSTRIA

There has been formed in Austria a national engineering standardizing body. It is called the "Normenausschuss der Osterreichischen Industrie" and is organized under the auspices of the "Hauptverband der Industrie Deutschosterreichs." The Secretary is Dr. Jaro Tomaides.

This is the tenth national standardizing body to be formed, the others being in Belgium, Canada, France, Germany, Great Britain, Holland, Sweden, Switzerland and the United States. With the exception of the British Engineering Standards Association, whose work dates from 1901, they have all been formed since the beginning of the European war.

NATIONAL RESEARCH COUNCIL

TO STUDY ELECTRICAL INSULATION PROBLEMS

The Division of Engineering of the National Research Council has entered into an extensive campaign to investigate the principles of insulation, a matter which is of vital importance to the electrical trade and to its consumers. A meeting of the Division's Insulation Committee was held recently at the laboratories of the Western Electric Company at 463 West Street. It was attended by nearly two score of the most prominent engineers in the country. The Chief Engineer of the Western Electric Company, Doctor F. B. Jewett who is chairman of the committee presided.

The Engineering Division for sometime past has been endeavoring to formulate a practical plan whereby cooperation between the universities, the industries and the National Research Council might be accomplished in attacking the problems involved in fundamental research upon insulating materials. The basic properties of insulating materials are not well understood. Just what are the things that make an insulating material serve its function of insulating things electrically are not known. In order to arrive at an understanding of why an insulator insulates, because of the tremendous magnitude of the problems involved, cooperative research seems necessary.

A preliminary meeting of this committee was held a year ago. At that time no definite plans were formulated that seemed feasible as methods of attack. At this meeting, however, it was decided that the first step is the gathering together of all the published and known scientific material relating to insulation. This is a tremendous undertaking, and the committee decided that a permanent salaried secretary should be engaged to carry on the compilation of the material which has already been published and to maintain continuity in the records and activities of the Committee. The committee also decided that it would attack the technical problems by providing some research men in the universities with funds and materials supplied by the industries, under the guidance of the National Research Council.

The scarcity of skilled and trained research men, who are capable of attacking these recondite insulation problems, is a matter of much concern to the Insulation Committee. An effort will be made to discover among the post-graduate students and the faculties of the universities, men who are able to do this work. The benefits to the electrical industry, if these questions are given satisfactory answer, will in all probability be so great that a measure of them in financial terms at this time would be extremely difficult. In fact, if made in terms of the vision of these far-seeing men, they would seem extravagant and altogether unbelievable.

The committee consists of 37 representatives from the electrical industries, the national engineering societies, the national scientific societies, the national manufacturing organizations and the universities and colleges of the country. Among those who attended the meeting were: Mr. C. E. Skinner, Westinghouse Electric & Manufacturing Co., Dr. Irving Langmuir, General Electric Co., Mr. Percy H. Thomas, Consulting Electrical Engineer, New York, Mr. William A. Del Mar, New York, Mr. D. W. Roper, Commonwealth Edison Co., Chicago, Ill., Dr. Clayton H. Sharp, Electrical Testing Laboratories, New York, Dr. John Johnston, Yale University, Professor Frederick Bedell, Cornell University, Professor A. E. Kennelly, Massachusetts Institute of Technology, Professor K. T. Compton, Princeton University, Mr. Edward D. Adams, Engineering Foundation, New York, Dr. Carl Hering, Consulting Engineer, Philadelphia, Pa., Mr. John M. Weiss, The Barrett Company, New York, Dr. Richard C. Tolman, Chemical Division, National Research Council, Washington, D. C., Dr. F. B. Silsbee, Bureau of Standards, Washington, D. C. and a number of others.

PROGRESS ON THE SAFETY CODE PROGRAM

Considerable progress has been made on the comprehensive program of safety codes being undertaken by a large number of organizations under the auspices and rules of procedure of the American Engineering Standards Committee. Following this regular procedure, each code is being formulated by a sectional committee, broadly representative of the interests concerned, and composed primarily of representatives designated by the various bodies interested in the particular code. The sectional committee is organized by one or more bodies designated for the purpose by the American Engineering Standards Committee and known as sponsors.

Sponsorships for the additional safety codes have been arranged as follows:

Construction Work. National Safety Council.

Electrical Fire Code. National Fire Protection Association.

Electrical Safety Code. Bureau of Standards.

Floor Openings, Railways and Toe Boards. National Association of Mutual Casualty Companies.

Lighting Code. Illuminating Engineering Society.

Lightning Protection. American Institute of Electrical Engineers and the Bureau of Standards.

Machine Tools. National Machine Tool Builders Association and the National Workmen's Compensation Service Bureau.

Mechanical Transmission of Power. National Workmen's Compensation Service Bureau, the International Association of the Industrial Accident Boards and Commissions, and the American Society of Mechanical Engineers.

Sanitation Code, Industrial. U. S. Public Health Service.

Stairways, Fire Escapes and Other Exits. National Fire Protection Association.

Textiles. National Safety Council and the National Association of Mutual Casualty Companies.

The following sponsorships have previously been announced:

Abrasive Wheels. The Grinding Wheel Manufacturers of the United States and Canada, and the International Association of Industrial Accident Boards and Commissions.

Foundries. American Foundrymen's Association and the National Founders' Association.

Gas Safety Code. Bureau of Standards and the American Gas Association.

Head and Eye Protection. Bureau of Standards.

Paper and Pulp Mills. National Safety Council.

Power Presses. National Safety Council.

Pressure Vessels, Non-fired. American Society of Mechanical Engineers.

Refrigeration, Mechanical. American Society of Refrigerating Engineers.

Woodworking Machinery. International Association of Industrial Accident Boards and Commissions and the National Workmen's Compensation Service Bureau.

The *Head and Eye Protection Code* has been completed, and the sponsor, the Bureau of Standards, has submitted the Code to the Main Committee for approval.

STANDARDIZATION OF ELEVATORS

Upon request of the American Institute of Architects and the Elevator Manufacturers' Association of the U. S., a conference of the various bodies interested in the question of the standardization of levators was called by the American Engineering Standards Committee to decide whether such standardization work should be undertaken, and if so, what the scope of the work should be. The conference was held in New York on September 21st, and was attended by representatives of the following organizations:

American Institute of Architects.
American Institute of Consulting Engineers.
American Institute of Electrical Engineers.
American Society of Mechanical Engineers.
American Society of Safety Engineers.
Bureau of Buildings (Manhattan).
Bureau of Standards.
Electric Power Club.
Elevator Manufacturers' Association of New York.
Elevator Manufacturers' Association of the U. S.
National Association of Building Owners and Managers.
National Fire Protection Association.
Supervising Architect's Office, U. S. Treasury Department.

After a full discussion, including such matters as platform sizes, speeds, accelerations, capacities, methods of test, pit and overhead clearances, well dimensions and hatchways, and safety provisions and appliances, the following resolution was unanimously voted:

RESOLVED: that this Conference fully recognizes the need and the desirability of standardizing such features of both passenger and material-handling elevators as capacities, platform sizes, and methods of test.

The relation of the standardization of the fundamental features of elevator to the elevator safety code now being formulated by the American Society of Mechanical Engineers, was fully considered and a committee was appointed to confer with the committee of the Society which is in charge of the code and arrange for cooperation.

A committee was appointed consisting of one representative from each body represented at the Conference to formulate plans for the organization of the work and to report its recommendations to the American Engineering Standards Committee.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

NEW YORK CITY AUTHORIZES INCREASE IN COMPENSATION OF ENGINEERING EMPLOYEES

Under a recent general readjustment of the salaries of municipal employees in the City of New York the compensation for all positions carrying a salary of less than $7500 per annum has been increased. In the case of salaries of less than $1500 the increase is at the rate of 22 per cent with a minimum of $200. In the case of salaries ranging from $1500 to $2500 per annum the increase is 20 per cent. To salaries upwards of $2500 per annum $500 has been added but salaries plus increases have been limited to a maximum of $7500.

The effect of these increases upon the compensation of the engineering force of the city as organized near the close of last year is shown in the following table, which also gives a comparison with the average compensation for the same positions as fixed before the shrinkage in the value of the dollar became pronounced. All of the positions are classified on the basis recommended by Engineering Council's Committee on Classification and Compensation.

Comparing the present average compensation with the compensation schedule proposed by the Committee, it will be seen that the average pay of Junior Aids and Junior Assistant Engineers under this scale is substantially greater than that tentatively recommended; that the average compensation for Aid is practically the same as that proposed by the Committee; that the average compensation for Senior Aid and Assistant Engineer is very close to the Committee's minimum; and that for the grades Senior Assistant Engineer, Engineer and Chief Engineer the average salary, after the allowed increases have been added and notwithstanding the appreciable betterment in the lower grades is still approximately $650 to $1,500 per annum below the minimum compensation proposed by the Committee.

Position	Number of Employees	Average Salary July 1, 1915	Average Salary After Aug. 20, 1920	Per cent increase
Chief Engineer (including Deputy Chief Engineer)	20	$7,270	$7,450	2
Engineer	50	3,850	4,470	16
Senior Assistant Engineer	86	2,850	3,420	20
Assistant Engineer	171	2,180	2,760	27
Junior Assistant Engineer	56	1,630	2,370	45
Senior Aid (Chief Instrumentman and Chief Draftsman)	64	1,700	2,440	44
Aid (Instrumentman and Draftsman)	285	1,500	2,180	45
Junior Aid (Junior Draftsman and Rodman)	150	1,030	1,720	67

FEDERATED AMERICAN ENGINEERING SOCIETIES

A. I. E. E. REPRESENTATIVES ON AMERICAN ENGINEERING COUNCIL

At the meeting of the Board of Directors of the A. I. E. E. held in Philadelphia, October 8, the following twelve members were appointed as the official representatives of the Institute upon the Am. Engineering Council, which is the governing body of the Federated American Engineering Societies, for the term beginning January 1, 1921, and also to represent the Institute at the organization meeting to be held in Washington, November 18-19, 1920:

Comfort A. Adams, Cambridge, Mass.
A. W. Berresford, Milwaukee, Wis.
H. W. Buck, New York, N. Y.
F. L. Hutchinson, New York, N. Y.
W. A. Layman, St. Louis, Mo.
William McClellan, Philadelphia, Pa.
L. F. Morehouse, New York, N. Y.
L. T. Robinson, Schenectady, N. Y.
Charles S. Ruffner, New York, N. Y.
Charles F. Scott, New Haven, Conn.
L. B. Stillwell, New York, N. Y.
Calvert Townley, New York, N. Y.

ADDITIONAL SOCIETY ACTIONS

The Joint Conference Committee takes pleasure in announcing five additional members of The Federated American Engineering Soceities:

Engineering Association of Nashville. On June 7, 1920 the Engineering Association of Nashville voted to become a Charter-Member of The Federated American Engineering Societies.

American Institute of Chemical Engineers. At its meeting of June 29, 1920, the American Institute of Chemical Engineers voted to join The Federated American Engineering Societies.

Engineering Societies of Buffalo. At the meeting of September 21, 1920, the Engineering Society of Buffalo voted, unanimously, that the Society become a Charter-Member of the Federated American Engineering Societies.

American Institute of Mining and Metallurgical Engineers. At its meeting of September 24, 1920, the Board of Direction of the American Institute of Mining and Metallurgical Engineers voted to become a Charter-Member of The Federated American Engineering Societies.

Society of Industrial Engineers. The Board of Directors of the Society of Industrial Engineers have voted to become a Charter-Member of The Federated American Engineering Societies.

CURRENT ENGINEERING TOPICS

MEETING OF BOARD OF SURVEYS AND MAPS

The new board of Surveys and Maps met with its advisory council on September 14th to receive reports of its committees and to appoint permanent members to the regular standing committees from the advisory council.

Owing to the fact that the time since the last meeting had been largely taken up by the vacation period in Government departments, only reports from the committees on Information, Technical Standards and Topographic Maps were ready for presentation.

The committee on information reported the results of its questionnaires sent to all Government map-making Bureaus which indicated that the Information Office should for the present carry on the work of indexing map data since it was feared that large amount of additional clerical work would be involved because of the change to the Harriman system at the present time. It urged the map-making Bureaus represented on the Board to furnish the Information Office with new data of maps as soon as these data could be prepared. A draft of a proposed popular bulletin on the Use of Mean Sea Level Datum for Spirit Level Valuation was submitted with the recommendation that it be prepared for publication. It was also announced that the Food Administration had presented the Information Office with about 100 copies of maps of countries of Europe and Asia.

In the report of the committee on Technical Standards the results of the committee's questionnaire were reviewed, it being pointed out that there was a sharply divided practise in this matter at the present time. Four of the Bureaus reporting employ the metric system, while eight use the English system; and it was unanimously recommended by the committee that the English system be adopted as standard practise. By English measurement is meant the scales upon which one inch on the maps bears an integral relation to feet or miles on the ground, as for example, 1000 feet to 1 inch, 2 miles to 1 inch, etc. By the metric measurement is meant the practise of employing "ratio" scales evenly divisible into one million such as 1:62500, 1:250,000, etcetera. The chairman of the advisory council has stated that when this comes before his council for recommendation a general questionnaire will be sent to as many interested engineers as possible, so that general engineering opinion may be obtained.

The committee on Topographic Maps made some specific recommendations which if followed out will be of value to hydraulic and drainage engineers and other technical users of maps.

The next regular public meeting will be held on the second Tuesday in November at ten o'clock in the Department of the Interior Building.

ACCOMPLISHMENTS UNDER THE FEDERAL WATER POWER ACT

When the Federal Water Power Act was approved on June 10th it concluded twelve years of effort for effective water power legislation. In accordance with the provision of the Act, the Secretary of War, Secretary of the Interior and the Secretary of Agriculture became a Commission to administer the Act. This Commission was not able to accomplish effective work for nearly a month after it was organized because its members were unable to arrange a common meeting time. At their first meeting, however, the Secretary of War was appointed chairman and Mr. O. C. Merrill, then chief engineer of the Forest Service, was appointed executive secretary. This put the Commission on a working basis and it immediately organized under Mr. Merrill's direction to take care of the applications for power permits which were already being received.

The work of the Commission was divided into engineering, accounting, statistical, regulatory, licensing, legal, and operation. The engineering division is regarded as the most important as it will make general investigations of the electric power industry, power sites, costs and developments. It will among other things report results of its examinations to Congress preparatory to construction work of the United States; will examine and revise plans for development of streams upon which applications for licenses are made; will consider construction plans

proposed by licensee; will when necessary make physical valuation of properties in rate-making proceedings; and when already existing plants are brought under the Act will fix the necessary stipulations as to maintenance, development and operation.

Up to the present time the following personnel have been assigned to the Commission: Lieut. Col. William Kelley, engineer officer; R. R. Rendell, Asst. engineer officer; Major L. W. Call, law officer and F. W. Griffith, chief clerk. With this small personnel the Commission has adopted a set of comprehensive regulations covering the procedure in connection with the securing of licenses and permits, and is handling applications at such a rate which if maintained will place under consideration before January 1st, 4,000,000 horse power.

While the regulations were being promulgated special hearings were held. Outside interests were invited to bring their recommendations before the Commission and a number of important changes resulted in the accepted principles. These included such questions as rental charges, amortization reserves, depreciation reserves, allocation of earnings and specifications covering the construction and maintenance of project works. In connection with these regulations the Water Conservation Committee of Engineering Council rendered a valuable assistance in response to specific inquiries from the Commission. These inquiries covered the subject of rental charges for water power licenses, including charges covering cost of Federal administration, use of Government lands and property, tribal lands within Indian reservations, the basis of expropriation above a specific rate of return, readjustment of charges, benefits from headwater improvement, allocation of earnings, depreciation and amortization. This committee of Engineering Council is still at the service of the Commission and is going deeply into the questions involved.

The regulations which were prepared at the September 3rd meeting were distributed about September 20th. Because of the wide variation in the applications which had been submitted to the Commission, they are all being returned to the applicants with a request that they be made to conform with the rules and regulations. This process will probably take considerable time because there are already over 60 applications, some of which involve a number of power sites. Up to October 1st four applications had been advertised.

The most important regulations so far promulgated are those numbered 9 and 10 dealing with permits and licenses respectively. They follow in complete form. Other regulations cover:

1. Definition of Terms.
2. Applications—General Requirements.
3. Applications for Preliminary Permits.
4. Applications for Licenses—Major Projects.
5. Applications for Licenses—Minor Projects.
6. Applications for Licenses—Major Projects Already Constructed.
7. Declarations of Intention.
8. Priorities and Preferences.
9. Permits.

a. Except as hereinafter provided, preliminary permits may be issued on the application of citizens, associations, corporations, States or municipalities desirous of obtaining licenses for the construction, maintenance or operation of dams, water conduits, reservoirs, power houses, transmission lines, or other project works necessary or convenient for the development and improvement of navigation, and for the development, transmission and utilization of power across, along, from, or in any of the navigable waters of the United States, or upon any part of the public lands and reservations of the United States (including the Territories), or for the purpose of utilizing the surplus water or water power from any Government dam.

b. Permits will be issued only for the purpose of enabling applicants to maintain their priorities while securing the data required for an application for license and will be for such periods, not exceeding a total of three years, as in the judgment of the Commission will be necessary for studying the proper location and design of the project; for making examinations, surveys, maps, plants specifications and estimates; for conducting stream measurements; for sinking test pits or making borings to determine foundations for dams or other structures; for securing a market for the power to be developed; for making financial arrangements; or for any other purpose necessary or desirable in the preparation of application for license.

c. Permits will not be issued for projects already constructed; for transmission lines alone; for projects of a power capacity of less than 100 horse power; for projects which, in the judgment of the Commission, do not come within the scope of its authority under the Act, or should be undertaken by the United States itself, or do not propose adequate schemes of development, or would unreasonably interfere with projects under permit, license or other authority theretofore granted; or for projects for which date sufficient for filing application for license are already available. Permit affecting any reservation will be issued only after a finding by the Commission that the proposed use will not interfere or be inconsistent with the purpose for which such reservation was created or acquired. Permits will not be issued until after the expiration of the publication period prescribed by the Act.

d. In acting upon applications for preliminary permits, and in determining preferences therefor, the Commission may in its discretion upon the request of any applicant or upon its own motion, hold hearing, order testimony to be taken by deposition, summon witnesses, or require the production of documentary evidence.

e. No charges will be made for permits, but permittees will be required as a condition of maintenance of priority, to perform such work and to make such studies and investigations, and such reports thereon, as in the judgment of the Commission may be necessary or desirable to enable both the applicant and the Commission to determine the feasibility, and the character and extent of development, which is proposed or which should be undertaken, which requirements will be expressed in the permit.

f. Upon a satisfactory showing of reasons therefore the Commission may authorize permittees to perform such construction work as may be necessary to maintain water rights under State Law, or as may be desirable in preparation for the construction of project works; but the granting of such authority shall not be deemed to have created any equities or to have established any rights beyond what would have been created or established had such authority not been given.

h. Each preliminary permit shall set forth the conditions under which priority shall be maintained and a license issued, and shall also set forth the essential terms and conditions of such license.

10. Licenses.

a. Except as hereinafter provided, licenses may be issued either in accordance with the provisions of preliminary permits or upon direct application therefor by citizens, associations, corporations, States or municipalities, for the purpose of constructing, operating, and maintaining dams, water conduits, reservoirs, power houses, transmission, and utilization of power across, along, from or in any of the navigable waters of the United States, or upon any part of the public lands and reservations of the United States (including the Territories), or for the purpose of utilizing the surplus water or water power from any Government dam.

b. Licenses will be issued for such periods, not exceeding fifty (50) years, as in the judgment of the Commission, will in each individual case, allow for the satisfactory development and operation of the project and protect the public interest, and shall remain in full force and effect for such periods unless surrendered or terminated as provided in these regulations or revoked as provided in the Act.

c. Licenses will not be issued for projects which, in the judgment of the Commission, do not come within the scope of its authority under the Act, or should be undertaken by the United States itself or do not propose adequate schemes of development, or lack satisfactory showing of financial ability, or would unreasonably interfere with projects under permit license, or other authority theretobefore granted, or would be opposed to the public interest. No license affecting the navigable capacity of any navigable waters of the United States will be issued until the plans of the dam or other structures affecting navigation have been approved by the Chief of Engineers and the Secretary of War. Licenses within any reservation will be issued only after a finding by the Commission that the license will not interfere or be inconsistent with the purposes for which such reservation was created or acquired. Licenses will not be issued until after the expiration of the publication period prescribed by the Act.

d. Licenses may be altered only upon mutual agreement between the licensee and the Commission. Any such alteration shall be made a part of the license and a substitute for the provision altered, but no such alteration shall operate to alter or amend or in any way whatsoever be a waiver of any other part, condition, or provision of the license.

e. Licenses may be surrendered only upon mutual agreement between the licensee and the commission and upon the fulfillment by the licensee of all obligations under the license, with respect to payment or otherwise, existing at the time of such agreement, and, if the project works authorized under the license are constructed in whole or in part, upon such conditions with respect to the disposition of such works as may be determined by the Commission.

f. Licenses may be terminated by written order of the Commission after such reasonable notice, not exceeding ninety (90) days, as the Commission may grant, if there is failure to commence actual construction of the project works within the time prescribed in the license, or as extended by the Commission. Under similar conditions and upon like

notice the authority granted under a license may be terminated with respect to any project works or separable part thereof covered by the license, if there is failure to begin construction of such project works or part thereof within the time prescribed in the license or as extended by the Commission; but no part of the project works shall be deemed separable for the purposes of this regulation unless so specified in the license.

g. Licenses may be revoked only through proceedings in equity instituted in a district court of the United States for a district in which some part of the project is situated, and in the manner provided in the Act.

(a) In case construction of the project works covered by the license, or of any specified part thereof, has been begun but not completed within the time prescribed in the license, or as extended by the Commission; or

(b) In case the terms of the license are violated by the licensee.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES (SEPT. 1-30, 1920).

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

ADVERTISING THE TECHNICAL PRODUCT.

By Clifford Alexander Sloan and James David Mooney. N. Y. and Lond., McGraw-Hill Book Co., Inc.; 1920. 365 pp., illus., 9 x 6 in., cloth, $5.

This book,—the work of two men experienced in advertising technical products, is a discussion of the more important factors of the problem. The subjects discussed are the economic elements of such advertising, the instruments available for it, the preparation of technical advertisements and advertising organizations. An interesting collection of actual advertisements, with critical comments, and a brief bibliography are included in the book.

FUEL OIL IN INDUSTRY.

By Stephen O. Andros. Chic., The Shaw Publishing Company, 1920. 214 pp., illus., tables, 9 x 6 in., cloth, $3.75.

The volume opens with a discussion of the physical and chemical properties of fuel oil, the principles of its combustion, a comparison of coal and oil as fuels and a description of "colloidal" fuel. This is followed by chapters on the storage and distribution of oil, methods of heating, straining and pumping, on the arrangement of boiler furnaces and on types of burners. The remaining portion of the book describes the applications of fuel oil in steamships, locomotives, iron and steel manufactures, heat treating, central stations, the sugar, glass and ceramic industries, and in heating buildings. The treatment is concise and practical rather than theoretical.

HANDBOOK FOR HEATING AND VENTILATING ENGINEERS.

By James D. Hoffman, assisted by Benedict F. Raber. Fourth edition, N. Y. & Lond., McGraw-Hill Book Co., 1920. 478 pp., illus., tables, 7 x 4 in., flexible cloth, $4.50.

Has Supplement: A Course of Instruction for Technical Schools with Questions, Problems and References. To be used in connection with the Handbook for Heating and Ventilating Engineers—Hoffman; 51 pp., 7 x 4 in., paper.

This volume is intended to fill the need of those engaged in the design and installation of heating and ventilating apparatus for a pocket-book covering the entire subject in simple form and containing the tables commonly used. The present edition has been entirely rewritten and reset, and considerably enlarged, to bring it into accord with present practise.

HYDRAULIC TABLES.

The elements of gaging and the friction of water flowing in pipes, aqueducts, sewers, etc.; flow of water over sharp-edged and irregular weirs and the quantity discharged. By Gardner S. Williams and Allen Hazen. Third edition, revised N. Y., John Wiley and Sons, Inc.; Lond., Chapman and Hall, Ltd., 1920. 115 pp., illus., plates, tables, 9 x 6 in., cloth, $2.

The third edition of these well-known tables has been carefully corrected and revised in minor points, and a new chapter has been added, in which the additional data that have accumulated during the fifteen years since these tables first appeared are examined to ascertain whether changes or adjustments in the formula are needed.

WINGS OF WAR.

An Account of the Important Contribution of the United States to Aircraft Invention, Engineering, Development and Production during the World War. By Theodore Macfarlane Knappen, with an introduction by Rear-Admiral D. W. Taylor. N. Y. & Lond., G. P. Putnam's Sons, 1920. 289 pp., plates, 8 x 6 in., cloth, $2.50.

The story of the United States army aircraft production program is essentially one of confident hopes, bitter disappointments, failures and successes such as inevitably attend the creation from nothing of an immense industrial organization. Until now, the history of this undertaking is chiefly found in the voluminous reports of investigating committees, which over-emphasize the failures and undervalue the successes. The present book is an attempt to supply a less one-sided account of the army air effort, one which will give a readable report of the problem, the methods used for its solution and the net results obtained.

THE OWNERSHIP AND VALUATION OF MINERAL PROPERTY.

Being an Elementary Treatise on the Nature of Mineral Interests and Royalties, and the Correct Method of Valuing such Property for the Purposes of Sale, Probate, and Rating and Taxation, together with a Statement of the Law relating to Rating and Taxation. By Sir R. A. S. Redmayne and Gilbert Stone. Lond. & N. Y., Longmans, Green and Co., 1920. 256 pp., 9 x 6 in., cloth, $4.50.

The primary object of this book is to assist the mining expert who desires to have available a statement of the interests involved and the mode of valuing those interests in the mining industry generally. The work consequently contains, in addition to chapters on royalties and valuation, a general explanation of the law relating to mining interests, wayleaves and subsidence, and also the law relating to the rating and taxation of mineral properties.

PERSONAL

G. S. McKee has been appointed Manager of Production of the Canton, Ohio plant of the Timken Roller Bearing Company.

J. C. Stevens and R. E. Koon have announced their new consolidation under the firm name, Stevens and Koon, Consulting Engineers, with offices in the Spaulding Building, Portland, Oregon.

F. M. Bond, who for the past six months has been Manager of the Corticelli Silk Mills (Nonotuck Silk Company) at Leeds and Haydenville, Mass., has been appointed General Manager in charge of all of the mills of the company, with headquarters at Florence, Mass.

L. F. Wood, who for the past year and a half has been acting as instructor of technical graduates, in the Chicago Central Station Institute, educational bureau of the Commonwealth Edison Company, has accepted an associate professorship in the department of Electrical Engineering, Iowa State College, Ames, Iowa.

Ernest H. Billipp has been commissioned to visit South America to make a preliminary investigation for starting a new industry there. His work will include both making arrangements for obtaining a government concession, and solving the engineering problems encountered. He is expected to remain as consulting engineer after the project is under way.

H. W. Hough, for the past ten years Chief Electrical and Research Engineer for the Cleveland Electric Illuminating Co., has joined the staff of the Daniel M. Luehrs Co., Industrial Consulting and Construction Engineers, Cleveland, Ohio. Mr. Hough is an engineer of recognized standing in the central station industry, with experience both in the design and in the solution of the many industrial problems which are incident to the supply of light and power; and he has been closely associated with prominent engineers throughout the country in his work on various committees of state and national engineering societies.

OBITUARY

Richard Lamb, an Associate of the Institute since 1895 and a Member since 1913, died on October 18, 1920. Mr. Lamb was born in Norfolk, Va., in 1859. He received his early education at several schools in Virginia, and in 1883 finished the course at Brown University, Providence, R. I. From that time on he was engaged in active engineering work, for the most part in designing and building various plants, being appointed as Chief Engineer by such companies as the Brooklyn Dock and Terminal Co., the Chauncey Realty Co., and the Virginia Copper Co., Ltd. Later he went into business as Consulting Electrical and Civil Engineer with offices in New York City. Besides being a Member of the A. I. E. E., Mr. Lamb was a Member of the A. S. C. E. and the A. I. M. E.

Phillip Ewing Hart, Chief Electrical Engineer, Burma Mines, Ltd., was instantly killed by an accident on August 10, 1920, at Namtu, North Shan States, Burma, British India. Mr. Hart's home was at Mulgrave House, Sutton, Surrey, England, where he was born in 1878. His schooling included the Mechanical and Electrical Engineering courses at London University, after which he did engineering work for various companies in both America and England. When the war broke out he was in South America, engaged on an engineering project there as Resident Engineer; but he left this work to return to England and join the army as a private, later receiving a commission. He was in active service with the artillery for over two years, when he obtained a transfer to the Royal Engineers, still remaining in active service as forward roads officer, and receiving the commission of captain. He was awarded the Military Cross in 1918. Mr. Hart was a Member of the A. I. M. E. and an Associate of the A. I. E. E.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Lynn.—August 30, 1920. Annual business meeting, and election of officers as follows: Chairman, L. C. Loewenstein; Vice-Chairman, F. J. Rudd; Secretary-Treasurer, D. F. Smalley.

Providence.—October 8, 1920. Providence Engineering Society's Rooms. Election of officers as follows: Chairman, Walter C. Slade; Vice-Chairman, Nicholas Stahl; Secretary-Treasurer, Frederick N. Tompkins. Mr. G. H. Roosevelt, of the Railway & Traction Department of the General Electric Company presented a paper prepared by himself and Mr. C. M. Gilt on "Automatic Systems for Lighting and Railway Service." This paper was illustrated by lantern slides. Mr. R. J. Wensley, Switchboard Engineering Division, Westinghouse Elec. & Mfg. Co., also presented a paper, illustrated by lantern slides, on "Industrial Automatic Substations". Attendance 60.

St. Louis.—September 30, 1920. Dinner meeting, American Annex Hotel. Resolution passed favoring representation of engineering bodies of St. Louis in the Federated American Engineering Societies. President A. W. Berresford was the speaker of the evening and delivered an informal talk on Institute affairs. Attendance 109.

Seattle.—September 21, 1920. Banquet Room, Hotel Butler. Annual dinner and get-together meeting. Informal talks were given by Dr. C. E. Magnusson, a Vice-President of the Institute, and Willis T. Batcheller, the Section's delegate to the Annual Convention at White Sulphur Springs, W. Va. Attendance 50.

Worcester.—October 8, 1920. E. E. Bldg., Worcester Polytechnic Institute. Speaker: Mr. S. T. Dodd, of Schenectady, N. Y. Subject: "The Electrification of the Chicago, Milwaukee & St. Paul." Attendance 130.

PAST BRANCH MEETINGS

Brooklyn Polytechnic Institute.—October 4, 1920. Election of officers as follows: Chairman, Arthur H. Wehle; Vice-Chairman, John Gluck; Secretary, A. Marvin Liebowitz; Treasurer, William F. Strobel. Attendance 30.

Bucknell University.—Electrical Laboratory, October 4, 1920. Short talks were given by the President and Professors Irland and Hall concerning the branch, its advantages and the prospects for the coming year. Details of the Electrical Laboratory were then explained to the new men. Attendance 38.

University of California.—September 22, 1920. Speaker Mr. Nadon, of the Westinghouse Company. Subject: "Motion Picture Apparatus and Storage Batteries." Attendance 21.

October 6, 1920. Speaker: Mr. H. S. Dusenbery. Subject: "Electrical Stage Effects, Magic and Illusions." Attendance 85.

University of Missouri.—September 20, 1920. Engineering Building. Speaker: Professor A. C. Lanier. Subject: "The History and Work of the A. I. E. E." Attendance 100.

North Carolina State College.— September 28, 1920. Professor Browne and Capt. Cox of the electrical engineering department, were present and gave a demonstration of wireless telephony and telegraphy. Attendance 48.

Ohio Northern University.—September 15, 1920. Dukes Memorial. Business meeting. Informal talks by Professor Molitor of the Electrical Department, and Professor Brakes of the Mechanical Department. Attendance 16.

September 22, 1920. Dukes Memorial. Subjects: "The Engineer and The Society" by W. L. Lynde, and "Electric Locomotive" by Paul Rice, data taken from the April JOURNAL written by N. W. Storer. Attendance 36.

October 6, 1920. Dukes Memorial. Speaker: Professor C. C. Carpenter. Subject "The Modern Applications of Electricity." Attendance 25.

Purdue University.—September 21, 1920. Electrical Building. Business meeting followed by talks: "Benefits Derived from Student Membership of A. I. E. E.," by Professor A. N. Topping; "Importance of Becoming a Student Member of A. I. E. E.," by Professor D. D. Ewing; "Engineering Societies," by Dean Potter; "The Field of Electric Railways" by C. J. Harding. The remainder of the evening was spent in a social gathering. Attendance 280.

West Virginia University.—October 4, 1920. Mechanical Hall. Election of officers as follows: Chairman, Max Wilcoxen; Vice-Chairman, J. M. Frum; Secretary, Hudson Chandler; Treasurer, A. C. Price. A short lecture was given by Professor A. H. Forman. Attendance 13.

ADDRESSES WANTED

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—James F. Elliott, Electric Controller & Manufacturing Co., Oliver Bldg., Pittsburgh, Pa.
2.—O. H. Horner, c/o Black & Veatch, 507 Interstate Bldg., Kansas ty, Mo.
3.—Wilfred Langille, Marion Station, Public Service Electric Co., Jersey City, N. J.
4.—H. S. Logan, 214 15th Street, Seattle, Wash.
5.—Alex. E. E. Mayo, Carnegie Institute of Technology, Pittsburgh, Pa.
6.—Leonard Morey, 1067 East 152nd Street, Cleveland, Ohio.
7.—P. J. Reese, 7th & Main Street, Royal Oak, Mich.
8.—L. F. Stoeltzing, 591 24th Street, Oakland, Cal.
9.—Richard G. Thomson, Alliance Power Co., Edmonton, Alberta, Can.
10.—J. Andre Wells, Western Electric Co., 463 West Street, New York, N. Y.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

MEN AVAILABLE

ELECTRICAL ENGINEER, 32, experience in line, substation and central station and industrial power work. Desires position with a public utility leading to executive responsibility or with a company holding or developing public utilities. E-2371.

TECHNICAL GRADUATE, 33, married, 8 years operating and supervising large and small coal carburated water gas properties, manager gas utility, community 7000, one year tool designing, automobile plant and one year purchasing and costs, auto trailer industry. Desires position with a future. Available on short notice. E-2372.

TECHNICAL GRADUATE, B. S. degree in Electrical Engineering. Three years experience as a draftsman, one year of which has been substation design. Would like position as Junior Engineer, but could consider position as draftsman if there is an opportunity to advance. Location N. Y. C. E-2373.

TECHNICAL GRADUATE, 34, married, Protestant. 18 years experience, machine shop, maintenance, drafting, designing, industrial substation layouts, conduits wiring diagrams, investigation reports on power plants, refrigeration plant improvements. Desire to connect with growing industrial organization. Prefer Newark, N. J., Conn. or Mass. E-2374.

GRADUATE ENGINEER, electrical, married. Six years experience with consulting engineer, and public utilities on utility problems (*i. e.* design and layout of distribution systems, appraisals, rate studies, etc.). Desires position with manufacturing company or consulting engineers on public utility industrial or sales engineering work. Vicinity of Cleveland, Toledo or Columbus preferred. E-2375.

GENERAL MANAGER, Public Utility Company, 18 years construction, operation, and development of small properties. Thoroughly versed in rate making and handling of municipal and public matters. Desires connection with consulting firm or larger utility. Age 39, married, present salary $4200. E-2376.

TECHNICAL GRADUATE, 24, 4½ years intimate acquaintance with power and substation equipment. Would like responsible position with some engineering concern vicinity Greater New York. Salary about $2500. Available immediately. E-2377.

ENGINEERING EXECUTIVE, 36, technical graduate. Experience in administration as well as in electrical, mechanical and industrial engineering lines. Now holding responsible position in production department of large manufacturing company. Will consider change for advancement. Salary dependent on opportunity to show results. E-2378.

COMMERCIAL ENGINEER, desires to make change. Graduate of University. Seven years electrical and mechanical experience and two years commercial experience in domestic and export transactions. Have worked for only the highest grade concerns. Wish to get into work which will give an opportunity to share in ownership or profits and management, having selected the experience so far obtained with this in view. E-2379.

GRADUATE ELECTRICAL ENGINEER, B. S. and E. E. degrees. Desires position with progressive firm as plant engineer. Twelve years experience in operation and testing of steam power plants, combustion and flue gas analysis, motor applications and wiring, heating and construction of factory buildings. Can furnish very best of references. E-2380.

ELECTRICAL ENGINEER, on construction or valuation work. Six years of railway, telephone, power, and distribution experience. Age 28. Salary expected $225 month. E-2381.

ELECTRICAL MECHANICAL ENGINEER, B. S. and E. E. Degrees. Ten years experience including railway electrifications, transmission systems, design and construction; central station construction and operation. Power application to industrial plants; electrical precipitation of smoke and

fume in industrial plant. Age 33, married. References. Salary $300. E-2382.

GRADUATE ELECTRICAL ENGINEER, (1909) married, age 31, desires position of greater responsibility in consulting and engineering. Has had factory and office experience, also erection, repair and executive experience with large industrial corporation. Capable of handling construction, erection and operation work. Salary $3000. Available at once. E-2383.

GENERAL SUPERINTENDENT, 10 years experience in charge of light and power work with large organization in East. Now employed but desires change. Married, age 33. Minimum salary $5000. E-2384.

ELECTRICAL ENGINEER, age 37, desires connection with industrial company, central station or manufacturing company. Technical graduate; eight years Westinghouse Service Department road and office duties. Five years factory test central station and large power and substation construction and maintenance. Location not a serious consideration. Prefer Middle or Southwest. E-2385.

POWER PLANT ENGINEER, design, construction, operation, technical graduate, 10 years' practical experience. Position desired in which thorough knowledge of power plant requirements will be useful. Also familiar with high tension lines and stations. Wish connection with sufficient prospects to warrant permanent location. 32, married; now with large engineering firm; wish to return to more specialized work. Available 30 days. E-2386.

ELECTRICAL ENGINEER, technical graduate. Broad engineering experience. Desires position with power company, consulting engineer, or construction company. Ten years' experience in power plant and substation work. Well versed in all subjects pertaining to the application of electricity for power purposes. Location Ohio or vicinity. Salary $3000. E-2387.

ELECTRICAL MECHANICAL ENGINEER, 24, technical graduate. Desires position with engineering construction and development firm, where opportunity for executive position in future is good. Foreign or domestic service. 1 year civil engineering, 4 years installation, manufacture and maintenance, 1 year assistant research engineer and inspector; present time power plant engineer. Available on short notice. E-2388.

ELECTRICAL ENGINEER, age 29, married. Desires position with firm handling or making industrial and power station equipment. Six years experience in purchasing, selling and handling of electrical equipment, also steam turbine and generator equipment. Salary $3000 per year. E-2389.

PUBLICITY & ADVERTISING EXECUTIVE, technical journalist. Formerly Assistant Editor of the largest Electrical publication in America and now Assistant Advertising Manager of one of the biggest electrical industries in U. S. Desires connection in similar capacity where initiative and executive ability assure position with unlimited future. Salary to start $2500. New York or vicinity. E-2390.

ENGINEER AND CERTIFIED PUBLIC ACCOUNTANT for assistant to high class business executive or connection with analytical organization. Exceptional experience in industrial analysis, factory cost accounting and system work, income tax procedure, engineering valuations, appraisals, investigations and reports. $7500 per year, minimum consideration. E-2391.

ELECTRICAL ENGINEER, desires business, engineering or sales position with growing concern. Experienced in manufacture test and correspondence and sale of electrical equipment. One year's active service as engineering and Radio officer in Air Service. Age 30, single. Available on short notice. E-2392.

ELECTRICAL ENGINEER, technical graduate with two years of varied test and development experience with large electrical power apparatus manufacturing concern, and one and one half years experience as chief tester with a small motor manufacturing concern, desires position with an industrial or power company. E-2393.

SALES MANAGER, or district manager, 40, married. E. E. degree. Sales and executive experience. $5000. E-2394.

ELECTRICAL ENGINEER, age 24, Graduate M. I. T. 1918. Desires change offering position with broader opportunities. Two years office and field work with large power corporation. Married. Salary $2500. Northern New York or New England States preferred. E-2395.

MANAGER AND ENGINEER, electric light and ice properties, age 40. Fifteen years experience construction, operation and managing small public service properties. At present with company operating properties in Texas. Wish to connect with larger company anywhere in the Southwest. E-2396.

ELECTRICAL ENGINEER, experienced in electrical installation and maintenance, including interlocking. No high-tension work. Eleven years experience in power, light, cranes, rotary convertors, pumps, engines, automatic control apparatus and circuit breakers. Available at short notice. E-2397.

GRADUATE ELECTRICAL ENGINEER, (M. E. E.) age 33, married. Nine years with present employer. Present work oversight of substation operation and care for large public utility. Familiar with line construction, maintenance, power and industrial plant design and construction. Wish to locate with consulting or contracting engineer, New York or New England with view to future financial interest. E-2398.

ELECTRICAL ENGINEER, 27, married, technical graduate, General Electric Test, experienced in design and distribution. At present assistant designing engineer with large company. Wish mid-western states location, with growing manufacturing concern. Initial salary $200 per month. E-2399.

SALES MANAGER, for manufacturing company desired by electrical engineer, 30, having nine years' broad business and engineering experience, possessing real sales and organizing ability and a forceful but pleasing personality. Salary $5000. plus small commission. Location preferred N. Y. C. E-2400.

TECHNICAL GRADUATE, age 28, desires position with chance for advancement. Not particular as to locality. Have had one year experience in transformer test of Westinghouse Electric and Mfg. Co. Two and one half years as Chief Electrician and in U. S. Navy. Available November 15, 1920. E-2401.

ELECTRICAL ENGINEER, 29, married, technical graduate 1915. At present Asst. Prof. Electrical Engineering. Desires commercial position in Middle West. Ability, capacity and willing worker. Broad engineering and business training. Future possibilities first, salary secondary. Available on reasonable notice. E-2402.

CONSTRUCTION ENGINEER, age 40, married, desire change to active construction work. Twenty years experience on central station and industrial work. At present designing automatic substation, 12000 kv-a., 33000 volts. Has had supervision of some of the largest electrical work in New England. Location New England or New York. Salary $3000. E-2403.

TELEPHONE TRANSMISSION INSPECTOR and Circuit Expert, one year college training, desires position with the Bell Telephone Company where initiative and ability are considered an asset. Age 28, good personality, married. Ten years' practical experience, highest references, salary $200. per month. E-2404.

YOUNG ELECTRICAL ENGINEER (1919) age 23, Spanish native tongue, with some technical and commercial experience, desires a position in Philadelphia. Willing to start at the bottom where there are good prospects of advancement. E-2405.

ELECTRICAL ENGINEER, 39, married, technically educated, eleven years broad experience on design construction and testing of power houses, substations and transmission lines. Desires opportunity for broader business training and development. E-2406.

GRADUATE ELECTRICAL ENGINEER. Twelve years experience designing, constructing, operating and appraising electrical properties, industrial plants, public utilities, etc. Position desired with progressive firm in North Central states capable of paying $3000 and up per year. Available after December 1st. E-2407.

PUBLIC UTILITY OPERATING MANAGER, Fellow A. I. E. E. desires engagement. Broad experience construction, operation and management light and power, railways and gas properties, steam and hydroelectric, large and medium size and high-tension transmission. Experienced with large organizations. Fine record public relations. American, perfect knowledge Spanish. E-2408.

OPPORTUNITIES

ELECTRICAL ENGINEER, one year out of college for sales work in New England. Sales experience not absolutely essential, but engineer of sales type, and who at the same time is capable from engineering standpoint. Work at present would consist chiefly of introducing line of electrical instruments. Man from Boston or vicinity preferred. Z-2310.

ELECTRICAL ENGINEERING GRADUATE to act as an engineering assistant in connection with preparation of estimates and proposals for service extensions to transmission and distribution system. Applicant can be a recent graduate or one with a few years' experience. Location Pa. Z-2307.

EDITOR, experience in power plant work. Application by letter only. Two men needed. Location N. Y. C. Z-2306.

SALESMAN AND EXECUTIVE to handle automobile department of an electrical concern, selling electric cars, industrial trucks and operate battery service station. Good position with great chance for development is open to the right man. Location N. Y. Z-2303.

EXPERIENCED GLASS MAN to take entire charge of Glass Works, both hand and machine bottles. Must understand machines making glass and the production end. Give full details of experience, age, salary expected and reference, in first letter. If not an A No. 1 glass man, do not answer this ad. Location Va. Z-2286.

LUBRICATING ENGINEER. Must be good citizen, know how to write the English language and have sufficient personality and address to talk with the Chief Engineers, Oilers and Presidents of the larger companies. Will be put into the grease plant for a few days. Then will compile from files every bit of information in regard to different industries. When information is compiled will be sent back on the road to two or three of the largest manufacturers of paper machinery to find out all he can in regard to lubrication and its bearing on paper machinery. Will call on two or three of the paper mills, at all times picking important ones so that the information will, first of all, be authentic and in the next place so that his call for help will serve as an introduction for this company, paving the way for future relations. When paper industry is completed it will be put into the hands of our salesmen and he will move on to the next industry. "What we are getting is, first of all, exact information; second, entree into plants where a salesman might need much longer time to get in; third, training for a real sales engineer because, when this man gets through with the principal industries, he will probably be better trained than almost any man in this country." Z-2274.

GRADUATE ELECTRICAL ENGINEER, preferably with some experience to prepare estimates for the expansion of the sub-station, and distribution system for new business and the preparation of proposals for contracts. Location Penna. Z-2275.

MECHANICAL ENGINEER familiar with design and operation of all forms of drying machinery and japanning ovens. Should have some intimate contact with this class of machinery, and especially in the construction of same. Location N. Y. City. Z-2276.

YOUNG ELECTRICAL ENGINEER with five or more years practical experience. Capable of working up proposals for equipment necessary for industrial plants of various kinds. Work is fairly broad, as business is transacted in foreign countries, buying the machinery and equipment here and shipping abroad, where we have our engineering staff who attend to erecting. Opportunity with great possibilities for the right man. Location New York City. Z-2277.

DRAFTSMAN with experience in electrical equipment for steel mills. Should also have power plant experience. Graduate Electrical Engineer desired. Location N. Y. City. Z-2268.

ELECTRICAL ENGINEER for power plant testing. Must have two years experience. Position permanent. Location New York City. Z-2262.

CHIEF ELECTRICIAN. Work consists of single and polyphase meter testing, motor testing, switchboard wiring, light and power wiring. General maintenance. Location Rhode Island. Z-2263.

MANAGER of Electric Department of Public Utilities. Location N. Y. Sate. Z-2241.

GRADUATE ELECTRICAL ENGINEER for power plant testing. Location Brooklyn, N. Y. Z-2244.

EXPERIENCED TRANSFORMER ENGINEER, one having experience on large power transformers. State in detail class of work previous experience has covered, and where at present employed. Location Canada. Z-2251.

ELECTRICAL ENGINEER. Young man, single, with good mechanical engineering knowledge. Chief duties would be electrical inspection of plant in the Nitrate Works. Good all-round man who would be able also to sell machinery when encountering any obsolete plant in Nitrate Works. Would also be needed at times in the absence of the Manager to take charge of office. Three years contract, passage and general living expenses paid. Location South America. Z-2231.

FOREMAN of electrical, mechanical instrument laboratory. Must be technical graduate or have had experience to substitute for such training. Also three section leaders with similar experience. Americans only. Four men needed. Location New Jersey. Z-2234.

RECENT GRADUATE, Electrical Engineer and Mechanical Engineer for development work on transmission and distribution for central station work in New York City. Z-2209.

MECHANICAL ELECTRICAL DRAFTSMAN with electric locomotive and multiple unit control car experience, as well as wiring and lighting equipment for steam cars. Location New York City. Z-2212.

MECHANICAL ENGINEER OR ELECTRICAL ENGINEER for sales work with battery company. Recent graduate will be considered. Location New York City. Z-2213.

ELECTRICAL ENGINEER for development of automatic regulating apparatus. Experience with voltage, current, speed regulation and water-wheel governors desirable. State age, experience and salary, and when available. Location Pa. Z-2216.

INSTRUCTORS in Electrical Engineering, two, will be appointed in February. Men with an unusually thorough grasp of fundamental electrical theory and a few years experience in engineering or teaching field are desired, although experience is not necessary. Appointees may pursue post graduate work. Location Wisconsin. Z-2220.

SALESMAN, preferably graduate Electrical Engineer with good sales experience but any engineer with broad sales experience will be considered. Company manufactures wires and cables. Location New York City. Z-2205.

DESIGNER for feed water heaters. Must have had experience in this line of work. Location Chicago, Ill. Z-2196.

MESSENGER for engineering company to look after office, etc. Should have high school education. Location New York City. Z-2203.

Long established technical school teaching courses in telegraphy and telephony, desires, for permanent position, a man capable of handling correspondence, and assisting in the preparation of textbooks on these subjects. Apply by letter, stating theoretical and practical training and salary expected. Z-2192.

TECHNICAL GRADUATE with 3 or 4 years experience, familiar with the design of electrical lay-out covering central station designing, underground duct lines, bus structures, conduit schedules, wiring diagrams and switchboard work. Location Mass. Z-2181.

MECHANICAL ENGINEER OR DESIGNER, air compressor expert, experienced in handling general experimental work independently; one able to figure cost and production. State fully experience, references and initial salary. Location New York City. Z-2185.

PHYSICIST who has had doctor's degree from two to five years. Experienced in general and electron physics. High grade man wanted. Location New Jersey. Z-2167.

ELECTRICAL ENGINEER for physical testing of lamp materials and general test on lamps. Must be able to take charge of laboratory. Graduate with two years experience. High grade man wanted. Location New Jersey. Z-2168.

RADIO AND RECTIFIERS TUBE ENGINEERS. Should be physicist on Electrical Engineering. Two men needed. One for radio tubes and one for rectifiers. Location New Jersey. Z-2169.

ORGANIC CHEMIST to have charge of chemical laboratory. Must be able to direct work and should have at least three years experience. In connection with experiment laboratory of U. S. Army, Air Service, Balloon & Airship Branch. Location Nebraska. Z-2175.

ENGINEER to look after mechanical end of power plant in China. Plant is about completed and will consist of two 2000 kw. Curtis Turbines. General Electric alternators 3000 volts, I and P Boilers (two batteries of 750 h.p.) Murphy stokers, superheaters, etc. Must have practical experience. Quarters will be furnished single man and $60. per month will be allowed married men for quarters. Location China. Z-2178.

PRODUCTION ENGINEER capable of superintending the construction and production of battery charging equipment, both for direct and alternating current. Must be familiar with rheostat, motor generator and switchboard design and capable of bringing the quality of our equipment up to the highest possible standard. Location Ohio. Z-1998.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED OCTOBER 8, 1920

ADAMS, REGINALD DOBSON, Electrical Engineer, Riccarton Borough Council, Riccarton, N. Z.
ALEXANDER, LOWELL M., Instructor in Physics, University of Cincinnati, Cincinnati, Ohio.
ALEXANDER, ROLAND B., Electrical Engineer, B. F. Goodrich Co., 206 W. Chestnut St., Akron, Ohio.
ALT, MILO S., Maintenance of Railway Converters& Substations, Iowa Railway & Light Co., Cedar Rapids, Iowa.
AMES, NORMAN B., Electrical Designer, The B. F. Goodrich Rubber Co., Akron, Ohio.
AMMANN, PHILIP G., Noma Motor Corp., 155 Avenue D, New York, N. Y.; res North Hackensack, N. J.
ANDREWS, BERTRAND HARDING, Supt. Hamilton Borough Council, Electric Power Station, Frankton Junction, Hamilton, N. Z.
ANTON, GEORGE, Electrician, Walker Electric & Plumbing Co., Lanett, Ala.
ARNOLD, HUGH T., Electrical Machine Designer, The Metropolitan Vickers Electrical Co., Trafford Park, Manchester, England.
AUSTIN, EUGENE H., Asst. Elec. Engineer, Lehigh Valley Coal Co., Wilkes Barre; res., 36 Wesley St., Forty Fort, Pa.
BARLOW, GODFREY F., Automatic Telegraph Supervisor, Great Northwestern Telegraph Co.; res., 212 Lee Avenue, Toronto, Ont.
BAUER, ERNST, Engineer, Electric Laboratory, U. S. Light & Heating Corp., Niagara Falls, N. Y.
BEAUDRY J. ARMAND, Engineer & Designer, Beland Electric Mfg. Co., 34 Southbridge St., Worcester, Mass.
BECKENBACH, FRANCIS H., Construction Dept., General Electric Co., Schenectady, N. Y.
BELFILS, GEORGES F., Asst. Chief Engineer, Societe Alsacienne de Constructions Mecaniques, Belfort, France.
BENNIS, STEPHEN, Cadet Engineer, New York Edison Co., Irving Place & 15th St.; res., 306 East 156th St., New York, N. Y.
BICKERSTAFF ERNEST, Distribution Foreman, Lake Coleridge Electric Supply, Public Works Dept., Addington, Christchurch, N. Z.
BRIGGS, ARTHUR P., Chief Engineer & Works Manager, Fabrica Tejidos Obregon, Barranquilla, Colombia, S. A.
BROWN, MICHAEL J., Engineering Dept., New York Edison Co., 15th St. & Irving Place, New York, N. Y.
BROWNSTEAD, JOHN P., Chief Engineer, Ashland Water Works, Ashland, Ky.
BRUALLA, FRANCIS, Technical Translator, Editorial Dept., *American Exporter*, 24 Murray St.; res., 138 W. 111th St., New York, N. Y.
BRYAN, FRANK A., JR., Trans. Engg. Dept., General Electric Co., Ft Wayne, Ind.
BUDD, CHESTER, E., Inspector, Western Electric Co.; res., 502 W. 136th St., New York, N. Y.
BUNYARD, FREDERICK C., Engineer, Cambridge District, Electric Power Board, Cambridge, New Zealand.
BUTLER, HAROLD A., Electrical Dept., Havana Electric Railway, Light & Power Co., Havana, Cuba.
BUYS, ORVILLE, Chief, Installation Section, Duquesne Light Co., 502 Chamber of Commerce, Pittsburgh, Pa.
CAPTOU, NICHOLAS J., Insideman, New York Telephone Co., 51 Nassau St.; res., 482 Park Avenue, Brooklyn, N. Y.
CARLO, R. E., South American Salesman, National Carbon Co., Inc., New York, N. Y.; Rivadavia 1253, Buenos Aires, Argentine, S. A.
CARR, WILLIAM W., Foreman Outside of Construction, Wenatchee Valley Gas & Electric Co., Wenatchee, Wash.
CAY, GEORGE, Industrial Electro-Chemist, 25 N. Jefferson St., Chicago, Ill.
CHACON, FERNANDO, E., Electrical Engineer, Chilian Electric Tramway & Light Co., Casilla 1557, Santiago, Chile, S. A.
COLE, GEORGE H., Electrical Construction Engineer, B. F. Goodrich Co.; res., 939 West Exchange, Akron, Ohio.
COLT FRANK B., Vice-President and Secretary, Bracket & Colt, Inc., 1400 Broadway, New York, N. Y.
COOTES, JOHN C. R., Electrical Superintendent Kennecott Copper Corp., Latouche, Alaska.
*CORREIA, JOAO NUNES, Chief Engineer, Moura, Gomes Netto & Co., Ltd., Avenida da Republica 66-4°-E, Lisbon, Portugal.
COUPLAND, RICHARD C., Capt., C. A. C., Officer in charge, Radiodynamic Torpedo Station, Gloucester, Mass.
COX, GEORGE ROBERT, Sales Engineer, Westinghouse Elec. Mfg. Co., 165 Broadway, New York, N. Y.
DAYMUDE, JOHN F., Repeater Attendant, American Tel. & Tel. Co.; res., 4110 Harvard Ave., Cleveland, Ohio.
DE FOREST, CHARLES S., Inspector, Southern New England Telephone Co.; res 335 Orange St., New Haven, Conn.
DENYES, PERCY, Chief Operator Hydro-Electric Power Commission, Campbellford, Ont.
DICK, HERMAN J., Asst. Electrical Engineer, Auto Call Co.; res., 40 N. Gamble St., Shelby, Ohio.
DOBSON, HARRY V., Electrical Contractor & Dealer; res., 138 E. Maple St., Stockton, Cal.
DOUCHET, F. A. J., Eléctrical Engineer, Ateleirs de Construction Electrique du Nord et del' Est, Cablerie de Jeumont, Nord, France.
DUNCAN, LEE J., Designer & Draftsman, Century Electric Co., 19th & Pine Sts., St. Louis, Mo.
DYER, FRANKLIN M., Engineering Asst., New England Tel. & Tel. Co., Boston; res., 76 Columbus Ave., Somerville, (42), Mass.
DYOTTE, WILBUR H., Engineering Dept., Western Electric Co., 463 West St., New York, N. Y.; res., 259 Stegman St., Jersey City, N. J.
EDWARDS, NICHOLAS C., Manager, Nicholas C. Edwards Ltd., Customs St. W., Auckland, N. Z.
ELDREDGE, WILLIAM S., Electrical Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
*EVANS, EARL R., Asst. Examiner, U. S. Patent Office; res., 1802 R St., N. W., Washington, D. C.
EYSTER, JAMES A., Laboratory Asst., Scoville Mfg. Co.; res., 86 Knoll St., Waterbury, Conn.
FERRIS, BENTLEY R., Meter Engineer, B. F. Goodrich Co.; res., 392 S. Main St., Akron Ohio.
FIEDLER, GEORGE M., Inspector, Western Electric Co., New York, N. Y.; res., 742 Emerson Ave., Elizabeth, N. J.
FITTS, JOEL A., Sales Engineer, Electric Storage Battery Co., 613 Marquette Bldg., Chicago, Ill.
FORBES, ALLAN C., Kellogg Switchboard & Supply Co., Adams & Aberdeen Sts., Chicago, Ill.
FRAGA, JOSÉ J., Commercial Engineer, General Electric Co. of Cuba, Apartado 1689, Havana, Cuba.
GILMORE, MARTIN L., Switchboard Engineer, A. S. D. Canadian General Electric Co., Toronto, Ont.
GILSON, WESLEY J., Supt., Houghton County Electric Light Co., Calumet, Mich.
GOSSET, EDWARD L., Power House Supt., Omanawa Falls, Tauranga, New Zealand.
GREEN, LEROY S., Manager, Baltimore Office, Aluminum Company of America, 1701 Lexington Bldg., Baltimore, Md.
GREEN, STANLEY S., Executive Secretary, Purdue University; res., 427 State St., W. Lafayette, Ind.
*GREENHUT, FREDERICK W., Designing Engineer (Automotive Engineering), 210 W. 54th St., New York; res., 107 Taylor St., Brooklyn, N. Y.
GUY, RICHARD W., Examiner, Electrical Standard Laboratory, Dominion Government; res., 451 Echo Drive, Ottawa, Can.
HARLAN, EARL, Telegraph Manager, Wire Chief, Atchison, Topeka & Santa Fe Railway Co., Sant Fe Depot, Fresno, Cal.
HAY, H. HARVEY, Asst. to Engineer, National Sugar Refining Co.; res., 223 Warburton Ave., Yonkers, N. Y.
HAYNES, PHILIP C., Asst. Technical Instructor, Railway Technical Schools of Y. M. C. A., Wodehouse Road, Bombay, India.
HAYWARD, CHARLES L., In charge of Electrical Work, The Measuregraph Co., St. Louis Mo.; 467 E. 23rd St., Brooklyn, N. Y.
HAZELTINE, HAROLD L., Eastern Representative, Sterling Varnish Co., Fulton Bldg., Pittsburgh, Pa.
HEFNER, W. ALBERT, Chief Electrician, McGraw-Hill Co., 10th Ave. & 36th St., New York, N. Y.
HEMPTON, FRANK, Electrical Engineer, Chandler, Colo.
HENNINGSEN, EARLE S., Designing Engineer, General Electric Co., Schenectady; res., 206 Root Ave., Scotia, N. Y.
HIDDLESON, WILLIAM A., General Manager, Watauga Power Company, & Bristol Gas & Electric Company, 15 5th St., Bristol, Tenn-Va.
HIGMAN, HENRY LAWTON, District Maintainance Supt., Ebro Irrigation & Power Co., Apartado 491, Barcelona, Spain.
HILL, EDWIN P., Maintainance Dept., Bethlehem Ship Building Corp., Alameda; res., 1901 Virginia St., Berkeley, Cal.

HILLEARY, WARREN, Superintendent, Royal Indemnity Co., 84 William St., New York, N. Y.
HOWGRAVE-GRAHAM, ROBERT P., Demonstrator & Lecturer, Northampton Polytechnic Institute; res., 21 Worsley Road, Hampstead, London, N. W. 3, Eng.
HUBBARD, GEORGE W., Mechanical Engineer, Graham, Anderson, Probst & White, 1417 Railway Exchange, Chicago, Ill.
INSEL, EMANUEL M., Electrical Draftsman, New York Edison Co., Irving Place & 15th St.; res., 1489 Vyse Ave., New York, N. Y.
JANSEN, ERNEST H., Consulting Engineer, 27 Rue de la Madeleine, Bruxelles, Belgium.
JONES, DAVID CLARENCE, JR., Design& Fire Prevention Engineer, Georgia Railway & Power Co.; res., 268 So. Ashby St., Atlanta, Ga.
KAHN, MAX, Chief Designer, General ElectricCo., Witton Works; res., 73 Station Road, Wylde Green, Birmingham, Eng.
KEUS, H. I., Manager, "Heemaf", Henegelo, (O) Holland.
KIGER PEARL R., Electrical Supervisor, Gatun Locks, Gatun, C. Z.
KNUTSEN, JOHN A., Chief Electrician, The Newport Company, Carrollville; res., 574 Linebarger Terrace, Milwaukee, Wis.
KOJIMA, TATSU, Electrical Engineer, Mitsubishi Electric Works, Kobe, Japan.
KRAMER, CHARLES H., Electrical Foreman, Union Gas & Electric Co., Cincinnati, Ohio; res., 927 Monroe St., Newport, Ky.
KRAUSE, JOSEPH F., Industrial Electrical Engineer, Mechanical Appliance Co.; res., 877 10th Ave., Milwaukee, Wis.
KRISHNASAMI, P. M., Asst. Shift Engineer, The Tata Hydro-Electric Power Supply Co., Power House, Khapoli, G. I. P. Ry., Bombay, India.
LEACH, GEORGE M., General Supt., Atlantic City Electric Co., Atlantic City, N. J.
LEWIS, RALPH, Electrical & Mechanical Engineer, Murray Engineering Co., 55 Duane St.; res., 53 East 96th St., New York, N. Y.
LOFSTRAND, ARTHUR L., Supt., Northwestern Power & Mfg. Co., Port Angeles, Wash.
*LOHR, FREDERICK T., Electrical Engineer, New York Pyrites Co., Inc., Gouverneur, N. Y.
LYONS, ABSALOM, Asst. Automatic Chief, Western Union Telegraph Co.; res., 452 Dayton St., Cincinnati, Ohio.
MALKIN, LOUIS, 155 Newport Ave., Brooklyn, N. Y.
MANDENO, LLOYD, Borough Engineer, Council Chambers, Tauranga, N. Z.
MANEGOLD, JOHN R., Chief Engineer, Dings Magnetic Separator Co.; res., 3025 Highland Blvd., Milwaukee, Wis.
MARTIN, HARRISON A., Test Asst., Westinghouse Electric & Mfg. Co.; res., 21 Liberty St., Asheville, N. C.
MARUYAMA, HAJIME, Electrical Machine Designer, Electrical Works, Mitsubishi Zosen Kaisha, Ltd., Kobe, Japan.
MARVIN, HARRY B., Electrical Engineer, General Electric Co.; res., 201 Division St., Schenectady, N. Y.
MASKEY, CARLE L., President, Peoples Heat & Power Corp., Westpoint, Va.
MATSUDA, SAICHI, Apprentice, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 1110 Center St., Wilkinsburg, Pa.
MCGEE, ROBERT F., Carolina Power & Light Co., Raleigh, N. C.
MIDGLEY, HARRY, Engineer, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, Eng.
MILLER, ANDREW MCM., Electrical Expert Aide, U. S. Civil Service Commission, Parris Island. S. C.
MILLIKEN, EARLE L., Asst. Manager, Blackstone Valley Gas & Electric Co., 1-3 Clinton St., Woonsocket, R. I.
MOORE, LOUIS D., Electrical Engineer, Missouri Pacific R. R., 1130 Railway Exchange Bldg., St. Louis, Mo.
MORRISON, HAL, Electrical Dept., Fairbanks, Morse & Co., 594 Whitehall St., Atlanta, Ga.
MULFORD, HAROLD C., 326 Colorado Ave., Bridgeport, Conn.
NAKAMURA, ICHIRO, Electrical Engineer, Takata & Co., 50 Church St., New York, N. Y.
NAKAZAWA, SHINJI, Head of Elec. Distribution Dept., Tokyo Electric Lighting Co., Tokyo, Japan.
NICHOLAS, FRANK R., Locating Engineer, Seattle Lighting Department, Seattle, Wash.
NICHOLS, ALBERT W., Supervisor of Electrical Equipment, Traffic Motor Truck Corp., 5200 N. 2nd, St. Louis, Mo.
NIWA, YASUJIRO, Electrical Engineer to the Electrotechnical Laboratory, Ministry of Communication, Tokyo, Japan.
NOYES, MAXWELL E., Asst. to Electrical Sales Engineer, Aluminum Company of America, 800 Chamber of Commerce Bldg., Pittsburgh, Pa.
O'CONNOR, HUGH, Manager, Cincinnati Office, Aluminum Company of America, 1406 Traction Bldg., Cincinnati, Ohio.
PAGE, SAMUEL T., Electrical Engineer, Construction Dept.' Utility Supply Co., 329 N. 4th St. Philadelphia, Pa.; res., Delanco, N. J.
PIASECKI, HARRY A., The Foundation Co., Dunlop, Black Rock; res., 252 May St., Buffalo, N. Y.
POLK, J. LANE, JR., Draftsman, Pennsylvania Railroad; res., 1409 10th St., Altoona, Pa.
POOLE, HOMER J., Asst. to Electrical Engineer, Llewellyn Iron Works, 1200 N. Main St., Los Angeles, Cal.
POWELL, ROLAND A., Draftsman, Ridgway Dynamo & Engine Co., 131 South St., Ridgway, Pa.
PRACK, J. BERNARD, Sales Engineer, Westinghouse Elec. & Mfg. Co., 314 N. Broadway, St. Louis, Mo.
RAVUT, CAMILLE L. M., Secrétaire, Générale, de la Societé Industrielle & Telephones, 25 rue de quartre Septembre, Paris 2nd, France.
REINHOLDT, PAUL H., Consumers Electrical Company, 119 W. Fifth St., Carroll, Iowa.
REYES, CEASAR A., Switchboard Operator, Braden Copper Co., Rancagua, Chile, S.A.,
ROYER. WALTER D., Industrial Sales Engineer, Robbins Electric Co., Pittsburgh, Pa.
RYAN, JAMES A., Electrical Estimator & Sales Engineer, Ryan & Dippel, 52 Vanderbilt Ave., New York; res., 581 St. Marks Ave., Brooklyn, N. Y.
SARRAT, FREDERIC J., Chief Engineer, Compagnie Generale de Railways et Electricité, 16 Rue du Congres, Bruxelles, Belgium.
SCHILLING, EUGENE W., Electrical Engineer, B. F. Goodrich Co.; res., 73 Belvidere Way, Akron, Ohio.
SCHRUMN, JEWETT F., Chief Electrician, French Mfg. Co., Robbins St.; res., 1243 W. Main St., Waterbury, Conn.
SEEM, RUSSELL W., Electrical Department, Pacific Electric Railroad, 6th & Main St., Los Angeles, Cal.
SELDIN, WILLIAM, 2919 Surf Ave., Coney Island, N. Y.
SITTERLE, EMIL, Engineer, L. K. Comstock & Co., 830 Guardian Bldg., Cleveland, Ohio.
SMITH, BISHOP FRANK, Student, Long Lines Dept., American Tel. & Tel. Co., 1413 Hurt Bldg., Atlanta, Ga.
SPILVER, FRED WILLIAM, Electrician, Goodyear Tire & Rubber Co. of California, 1249 E. 51st, Los Angeles, Cal.
SPRAY, GEORGE C., Electrical Draftsman, Switchboard Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
TADLOCK, J. HUBERT, Designing Engineer, General Electric Company, Schenectady, N. Y.
TANG, MIN KAO, Graduate, Harvard Engineering School, Cambridge, Mass.; res., Kiangpek City, Chungking, China.
THRANE, CHARLES H., Sales Agent, Transmission Dept., Pacific States Electric Co., 236 So. Los Angeles St., Los Angeles, Cal.
TONNESEN, SIGVALD M., Asst. Electrical Engineer, B. F. Sturtevant & Co., Hyde Park, Boston; res., 177 Wachusetts St., Forest Hills, Mass.
TORO-KEY, A. E., Venezuelian Legation, 1406 Massachusetts Ave., Washington, D. C.
TRAVIS, JULIAN T., Station Operator, Kansas City Power & Light Co.; res., 644 Barnett Ave., Kansas City, Kans.
TURNER, ROBERT C., Supt of Electrical Affairs, City of Atlanta, City Hall, Atlanta, Ga.
VAN WICKLE, CHARLES F., Electrical Engineer, Silk Producers Corporation; res., 423 Main St., Hackensack, N. J.
VILSTRUP, ASGER, Asst. Engineer, British Columbia Electric Railway Co., Ltd., Vancouver, B. C.
WARRINGTON, C. M., Research Engineer, The Ohio Service Co., Coshocton, Ohio.
WEAVER, GEORGE S., Relief Operator, Union Electric Light & Power Co.; res., 2716½ Caroline St., St. Louis, Mo.
WEIR, JAMES, Journeyman Electrician;res., 45 Connecticut Ave., Somerville, Mass.
WERNER, PIERRE R., Engineer, International Radio Tel. Co.. 325 Broadway, New York, N. Y.
WHITE, E. SHERMAN, Manager of Agencies, Metropolitan Elec' Mfg. Co., Long Island City, N. Y.
WIGGIN, PARKER E., Experimental Engineer (Radio), Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 4614 Henry St., Pittsburgh, Pa.
WILFORD, GEORGE MCLEAN, Asst. to Manager, National Electrical & Engineering Co. Ltd., Wellington, N. Z.
WILKINSON, HAROLD B., Substations Engineer, Chilian Electric Tramway & Light Co., Casilla 1557, Santiago, Chile, S. A.
WILLINK, FREDERIK R., Manager "Hemef", Henegelo O, Holland.
WOLFE, JOHN F., Foreman Electrician, Fidelity Electric Co.; res., 625 St. Joseph St., Lancaster, Pa.
WOLLE, JAMES L., Construction Foreman, General Electric Co., Witherspoon Bldg., Philadelphia, Pa.

WOOD, WILLIAM W., Sales Manager, Witton Engineering Dept., General Electric Co., Ltd., Witton, Birmingham, Eng.
YOUNG, RUSSELL H., Puget Sound Traction, Light & Power Co., 606 Electric Bldg., Seattle, Wash.
Total 156.
*Former enrolled students.

ASSOCIATE RE-ELECTED OCTOBER 8, 1920

CHESTERMAN, FRANCIS J., Chief Engineer, The Bell Telephone Company of Pennsylvania, 1631 Arch St., Philadelphia, Pa.

MEMBERS ELECTED OCTOBER 8, 1920

ADAMS, WILLIAM B., Chief Electrical Engineer, Central Power Dept., Rio Tinto Co., Huelva, Spain.
BERTRAND, PHILIP A., Secretary & General Manager, Grays Harbor Railway & Light Co.; res., 604 Essex Ave., Aberdeen, Wash.
DAVIS, ALTON F., Sales Manager, The Lincoln Electric Co., Cleveland, Ohio.
INGLEBY, HENRY S., Commercial & General Manager, Ingleby & Co., Ltd., 1 Albion St., Leeds, England.
MILLER, W. WEBSTER, Engineer, The Cutler-Hammer Mfg. Co.; res., 537 Tinton Ave., New York, N. Y.
MITCHELL, ROBERT B., Engineer & Manager, Glasgow Corporation Electricity Department, 75 Waterloo St., Glasgow, Scotland.
PLIMPTON, BENTLEY A., Sales Manager, The Locke Insulator Mfg. Co., Victor, N. Y.
POWEL, CHARLES A., General Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 634 So. Linden Ave., Pittsburgh, Pa.
WAGNER, GERALD J., Director of Public Service, City Hall, Grand Rapids, Mich.

MEMBER RE-ELECTED OCTOBER 8, 1920

LEWINSON, LEONARD J., Engineer of Lamp Tests, Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

FELLOWS ELECTED OCTOBER 8, 1920

COLLIER, WILLIAM R., General Sales Manager, Georgia Railway & Power Co., Atlanta, Ga.
MITSUDA, RYOTARO, Doctor of Engineering, Electrotechnical Laboratory, Ministry of Communications, Tokyo, Japan.
SCHULZ, THOMAS NORBERG, Director of Electricity Works, Kristiania, Norway.

TRANSFERRED TO GRADE OF MEMBER OCTOBER 8, 1920

ANDERSON, STEWART W., Adjunct Prof. of Elec. Engg., Virginia Military Institute, Lexington, Va.
ANDREWS, SAMUEL, W., Asst. Plant Engr., Niagara Power Development, Hydro-electric Power Commission, Niagara Falls, Ont.
BAIRD, HOBART B., Electrical Engineer, United Gas & Electric Engineering Corp., New York, N. Y.
BALDWIN, JOHN R., Electrical Engineer, Republic Flow Meters Co., Chicago, Ill.
BLALOCK, GROVER C., Instructor in Electrical Engineering, Purdue University, Lafayette, Ind.
BOYAJIAN, ARAM, Development & Research Engineer, General Electric Co., Pittsfield, Mass.
CODE, ELDEN S., Sales Engineer & Switchboard Designer, Westinghouse Elec. & Mfg. Co., Seattle, Wash.
COSTELLO, W. H., Sales Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
DUSTIN, FRED G., President, Standard Electric Service Co.' Minneapolis, Minn.
FAWCETT, CHARLES DEVAN, Asst. Prof. of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.
FAWELL, THOMAS A., Chief Draftsman, Anderson, Meyer & Co. Ltd., Shanghai, China.
FRIDAY, ELLSWORTH C., District Manager, Corliss Carbon Company, Chicago, Ill
GODDARD, RALPH W., Dean of Engineering, Professor of Electrical Engineering, New Mexico College of Agriculture & Mechanic Arts, State College, N. M.
GOETZENBERGER, RALPH L., Major, Ordnance Dept., U. S. Army, Frankford Arsenal, Philadelphia, Pa.
HAIL, JOSEPH C., Electrical -Engineer-in-Charge, Dept. of Electricity, City of Chicago Chicago, Ill.
KNOST, CHAS. P., Salesman, Westinghouse Elec. & Mfg. Co., New Orleans, La.
LUND, CHARLES A. Distribution Engineer, Tacoma Light Dept., Tacoma, Wash.
MCBRIAN, EDWARD W., Mechanical Engineer, Fox Bros. & Co., New York, N. Y.
MCGRATH, WILLIAM H., Vice-President, Puget Sound Power & Light Co., Seattle, Wash.
MATTHEWS, HOWARD D., Prof. of Elec. Machine Design, School of Engineering of Milwaukee, Milwaukee, Wis.
MULLEN, CLYDE A., Engineer of Tests, The Ohio Service Company, Coshocton, O.
NEWTON, JOHN M., Chief Engineer, The Roland T. Oakes Company, Holyoke, Mass.
O'CONNELL, WILLIAM T., Estimator & Designer, Elec. Div., Panama Canal, Balboa Heights, C. Z.
OSTER, EUGENE, Electrical & Mechanical Director, The Ault & Wiborg Co., Cincinnati, Ohio.
OWENS, JAMES W., Welding Aid & Asst. Shop Supt., U. S. Navy Yard, Norfolk, Va.
PARKER, SAMUEL R., Engineer of Plant, Saskatchewan Government Telephones, Regina, Sask.
RICH, EDWARD P., Consulting Engineer, Chicago, Ill.
ROWE, E. C., Chief Draftsman, Commonwealth Edison Company, Chicago, Ill.
SEARS, GEORGE C., Supt., White River Division, Puget Sound Power & Light Co., Dieringer, Wash.
SHOEMAKER, JOSEPH J., Supt. of Public Utilities, Town of Sibley, Sibley, Ia.
TOLMAN, CLARENCE M., Moose Mountain Ltd., Sellwood, Ont.
TRAVER, O. C., Supervising Designing Engineer, Switchboard Dept., General Electric Co., Schenectady, N. Y.
WEGG, DAVID S., JR., Sales Engineer, Allis-Chalmers Mfg. Co., Chicago, Ill.
WENTWORTH, HERBERT H., Industrial & Railway Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
WILKINSON, C. T., Engineer & Manager, Milliken Manufacturing Syndicate, London, England.
WILSON, N. P., District Service Manager, Westinghouse Elec. & Mfg. Co., Seattle, Wash.
WOODCOCK, LANCELOT R., Resident Engineer, Riegos y Fuerza del Ebro, Barcelona, Spain.

TRANSFERRED TO GRADE OF FELLOW OCTOBER 8, 1920

GRAHAM, EARL A., General Manager & Chief Engineer, Compania Panamena de Fuerza y Luz, Ancon, Canal Zone.
LUNDY, AYRES D., Member of Firm, Sargent & Lundy, Chicago, Ill.
STEVENS, WILLIAM C., Sales Manager, The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held September 27, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary

To grade of Fellow

BIRD, WILLIAM L., Manager, Secretary, Director, Kaministiquia Power Co., Fort William, Ont.
BRANDON, EDGAR T. J., Electrical Engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ont.
MOREHOUSE, LYMAN F., Equipment Development Engineer, American Telephone & Telegraph Co., New York, N. Y.
WYNNE, FRANCIS E., Manager, Railway Equipment Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

To grade of Member

BENJAMIN, REUBEN B., President, Benjamin Electric Mfg. Co., Chicago, Ill.
BILLIP, ERNEST H., Partner with J. J. Naugle, New York, N. Y.
BOVEE, BENEDICT A., Professor of Experimental Electrical Engineering, School of Engineering, Milwaukee, Wis.
BRADEN, NORMAN S., Vice-President, Canadian Westinghouse Co. Ltd., Hamilton, Canada
BUCHANAN, EDWARD V., General Manager, Public Utilities Commission, London, Ontario
CARLSON, FREDERICK W., Supt. of Electrical Dept., Davison Chemical Co., Curtis Bay, Md.
ELLIOTT, LOUIS, Steam Plant Engineer, Electric Bond & Share Co., New York, N. Y.
FLANDERS, CHARLES K., Captain, Signal Corps, U. S. A., New York, N. Y.
GIBBS, GEORGE S., Sales Engineer, Representative, Westinghouse Elec. & Mfg. Co., Boston, Mass.
HERTNER, JOHN H., President, Hertner Electric Co., Cleveland, O.
NEILD, JAMES F., Supt. of Substations, Toronto Railway Co., Toronto, Ont.
ROBERTS, EDWARD A., Engineer, John A. Beeler, New York, N. Y.

SCHWARZE, FRED, Electrical Engineer, Pfister & Vogel Leather Co., Milwaukee, Wis.
SHUCK, GORDON R., Instructor in Electrical Engineering, University of Washington, Seattle, Wash.
UPSON, WALTER L., Professor Electrical Engineering, Washington University, St. Louis, Mo.
WOOLHISER, H. L., Business Manager, Village of Winnetka, Winnetka, Ill.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1920.

Adair, Samuel E., New York, N. Y.
Allen, Roy N., (Member), Seattle, Wash.
Ames, Robert P., St. Louis, Mo.
Archiable, George W., Cincinnati, Ohio
Arnold, William E., Southbridge, Mass.
Avery, William Y., (Member), Bayonne, N. J.
Ayliffe, Harold E., St. Louis, Mo.
Bangratz, Ernest G., Boston, Mass.
Barnett, Brinkley, Lexington, Ky.
Bauer, M. Earl, E. Pittsburgh, Pa.
Beauchamp, Leon, Montreal, Que.
Beregh, Theodore J., New York, N. Y.
Blaisdell, Leonard T., Washington, D. C.
Bolick, Clarence P., Wilkinsburg, Pa.
Boring, Maynard M., Schenectady, N. Y.
Bottimer, Gordon W., Schenectady, N. Y.
Brennan, Gerard, New York, N. Y.
Brown, Pliny B., Lockport, Ill.
Brubaker, Henry W., Lancaster, Pa.
Carey, Thomas E., Denver, Colo.
Cariss, Carrington C., Brantford, Ont.
Catsells, Armando, Schenectady, N. Y.
Cheney, Stuart K., Toronto, Ont.
Conroy, Francis D., Boston, Mass.
Cuddy, Edward M., Syracuse, N. Y.
Currin, Robert H., Portland, Ore.
Elliott, John S., Providence, R. I.
Elsberry, Arthur D., Cincinnati, Ohio
Evans, A. Emerson, Germantown, Philadelphia, Pa.
Feinsilber, Morris, New York, N. Y.
Fendrich, William, Jr., Brooklyn, N. Y.
Ferguson, D. C., Toronto, Ont.
Flake, G. Raymond, Burnham, Pa.
Flynn, Charles C., Detroit, Mich.
Foley, James J., Cincinnati, Ohio
Garner, Clarence L., Portage, Wash.
Gealy, Edgar J., Wilkes-Barre, Pa.
Geyer, Delbert G., Syracuse, N. Y.
Green, John C., Akron, Ohio
Graves, Elwood L., Washington, D. C.
Graham, George A., Baltimore, Md.
Guard, James R., Philadelphia, Pa.
Hammond, Jackson A., Bluefield, W. Va.
Headings, William W., Bellevue, Ohio
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A complete list of the 37 Sections and 64 Branches of the Institute, with the names of the chairmen and secretaries, will be found in the October 1920 issue of the Journal and will be published again in the January issue.

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HANS CHRISTIAN OERSTED

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The Epoch-Making Discoveries of the Years 1819 and 1820*

BY ELIHU THOMSON

General Electric Co., Lynn, Mass.

IT is fitting that in Philadelphia we should celebrate the centenary of the great discoveries in electromagnetism. It was here that Franklin's investigations in electricity were made, culminating in the kite experiment. It was here that he and a few confreres founded the American Philosophical Society which became a national institution for the spread of that spirit of science and philosophy characteristic of Franklin. It was here not many years ago that under its auspices a very notable commemoration of the centenary of Franklin's work was held. Not far from here in Princeton the pioneer work of Henry in electromagnetism, induction of currents, and oscillations was done nearly a century ago. Not far to the south from here the first Morse telegraph line was established in 1844. In Philadelphia, Robert Hare in the early years of last century did his work with voltaic batteries. Here Bell first exhibited his speaking telephone at the Centennial Exhibition of 1876, calling such witnesses as Sir William Thomson (Lord Kelvin) to hear it speak. Not far from here, in the Laboratory of Edison in Menlo Park, the incandescent lamp was born in 1879. Here again in commemoration of Franklin was established the Franklin Institute, the influence of which has been so marked a factor in science and the mechanic arts everywhere. Under its auspices the first investigation of the electrical properties of the dynamo was made in 1877, and the first Electrical Exhibition held in America in 1884, the Paris Exposition of 1881 being the only forerunner. It is a pleasure to note at this time the possibility of great and increasing lustre to its future in the electrical field has come by a large bequest from one whom the present speaker knew well in his old Philadelphia days, Mr. Henry Bartol. I am reminded that the first meeting of the American Institute of Electrical Engineers was held at Philadelphia. And now, to speak very briefly of more intimate but infinitely less important matters, may the speaker modestly add that here over fifty-five years ago he built his first electrical machine, voltaic piles, batteries, electromagnets and telegraph, acquiring through them in his early years an insight into the science of electricity as it then existed. It was here that he taught science for ten years in the old Central High School at Broad & Green streets and that during this period in 1875 there was made, incidentally, the first wireless transmission, using induction coil, spark gap, ground and radiating conductor, briefly described in the *Franklin Institute Journal* of the time, and recently related more in detail by Professor M. B. Snyder of the school. It was here in Philadelphia that the speaker did his first electrical engineering, and definitely chose that professional career which has kept him alive and busy ever since.

There are times when an epoch-making discovery gives rise to a new science or art, or opens up entirely new fields for experimental research. When this has occurred before our time we can at best visualize the antecedent conditions imperfectly. The background of such a discovery as was made in 1819 by Hans Christian Oersted of Copenhagen, and announced in July 1820, is scarcely reproducible now. We shall not attempt to do so. Simple as was the experiment of Oersted, the fundamental character of his results was instantly recognized by his contemporary leaders in science, such as Ampere, Arago, Biot, Davy and Faraday who repeated the experiments, and served to stimulate them to an intensity of research work which at once brought wonderful additions to human knowledge.

Oersted, a Dane, born in 1777, was educated at the University of Copenhagen, and in 1806 occupied the chair of Physics there. Though he had already done important work, he was immortalized by his being the first to discover and investigate the effects of a current in a conductor upon a magnetized needle. It was, or at least may now seem to us, a most simple discovery, the outcome of experiments of equal simplicity. Nevertheless, subsequent events soon proved it to be the foundation stone upon which now rests the great science of electromagnetism. Oersted found

*Address delivered at the Philadelphia Meeting of the A. I. E. E., October 8, 1920.

that a wire conveying the current of a voltaic battery, such wire being called by him a "conjunctive wire," affected a freely pivoted magnetic needle in such a manner that the needle tended to set itself at right angles to the wire. The deflection was shown to be definite as to direction, depending on the direction of the current in the wire, the position of the poles of the needle and the relation of positions of the wire and the needle. It was recognized, also, that if the magnet were fixed in position and the conjunctive wire free to move, corresponding movements of the wire would take place. This discovery was given out in a brief work in Latin, the title of which was, in substance, "Experiments Concerning the Effect of Electric Conflict on the Magnetic Needle."

Oersted had apparently convinced himself long before of there being a necessary connection between electricity and magnetism and had held, perhaps more pertinaciously than others, to this view. In recognition of the great scientific value of his discovery the prize of the French Institute was awarded to him. This had already been given to Davy for his electrochemical discoveries, such as that of the separation of the alkali metals, sodium and potassium, from their compounds. Oersted also received the Copley medal of the Royal Society of London, and was honored by the distinction of Knighthood. Dying in 1851 at seventy-four, he had lived to see great progress in electromagnetism and to witness some of its early applications to the needs of mankind, such as the telegraph.

The following translation of Oersted's description appears in Barlow's "Magnetic Attractions," a book published in 1824. After assuming current passing in the conjunctive wire—

Let the straight part of this wire be placed horizontally above the magnetic needle properly suspended and parallel to it. If necessary, the uniting wire is bent so as to assume a proper position for the experiment. Things being in this state the needle will be moved, and the end of it next the negative side of the battery will go westward.

If the distance of the uniting wire does not exceed three-quarters of an inch from the needle the declination of the needle makes an angle of 45 deg. If the distance is increased, the angle diminishes proportionally. The declination likewise varies with the power of the battery.

The uniting wire may change its place, either towards the east or west, provided it continues parallel to the needle, without any other change of the effect than in respect to its quantity. Hence the effect cannot be ascribed to attraction; for the same pole of the magnetic needle which approaches the uniting wire, while placed on its east side, ought to recede from it when placed on the west side, if these declinations depended on attractions and repulsions. The uniting conductor may consist of several wires or metallic ribbons connected together. The nature of the metal does not alter the effect, but merely the quantity. Wires of platinum, gold, silver, brass, iron, ribbons of lead, and tin, a mass of mercury were employed with equal success. The conductor does not lose its effect, though interrupted by water, unless the interruption amounts to several inches in length.

The effect of the uniting wire passes to the needle through glass, metals, wood, resin, stoneware, stones, for it is not taken away by interposing plates of glass, metal or wood. Even glass, metal and wood interposed at once do not destroy, and indeed scarcely diminish the effect. The disk of the electrophorus, plates of porphyry, a stoneware vessel even filled with water were interposed with the same result. We found the effects unchanged when the needle was included in a brass box filled with water. It is needless to observe that the transmission of effects through all these matters has never before been observed in electricity and galvanism. If the uniting wire be placed under the magnetic needle, all the effects are the same as when it is above the needle, only they are in opposite directions; for the pole of the magnetic needle next to the battery declines to the east.

That these facts may be more easily retained, we may use this formula: the pole above which the negative electricity enters is turned to the west; under which to the east.

If the uniting wire be so turned in a horizontal plane as to form a gradually increasing angle with the magnetic meridian, the declination of the needle increases, if the motion of the wire be toward the place of the disturbed needle; but it diminishes if the wire moves further from that place.

When the uniting wire is situated in the same horizontal plane in which the needle moves, and parallel to it, no declination is produced either to the east or to the west; but an inclination takes place, so that the pole next which the negative electricity enters the wire is depressed when the wire is situated on the west side, and elevated when situated on the east side.

If the uniting wire be placed perpendicularly to the plane of the magnetic meridian, whether above or below it, the needle remains at rest, unless it be very near the pole; in that case the pole is elevated when the entrance is from the west side of the wire and depressed when from the east side.

When the uniting wire is placed perpendicularly opposite to the pole of the magnetic needle and the upper extremity of the wire receives the negative electricity, the pole is moved toward the east; but when the wire is opposite to a point between the pole and the middle of the needle the pole is moved towards the west. When the upper end of the wire receives positive electricity, the phenomena are reversed.

If the uniting wire be bent so as to form two legs parallel to each other, it repels or attracts the magnetic poles according to the different conditions of the case. Suppose the wire placed opposite to either pole of the needle, so that the plane of the parallel legs is perpendicular to the magnetic meridian, and let the eastern leg be united with the negative end, the western leg with the positive end of the battery, and in that case the nearest pole will be repelled either to the east or west, according to the position of the plane of the leg. The eastmost leg being united with the positive and westwards with the negative side of the battery, the nearest pole will be attracted. When the plane of the legs is placed perpendicular to the place between the pole and the middle of the needle, the same effects occur, but reversed.

A brass needle suspended like a magnetic needle, is not moved by the effect of the uniting wire. Needles of glass and of gumlac remain likewise quiescent.

On first thought it may seem singular that as many as twenty years elapsed after the Galvani and Volta discoveries, before such a simple experiment as that of Oersted was tried. The only hint or suggestion of prior observation appears in the statement that about 1802 Romagnasi of Trent (a town in the Austrian Tyrol) had noticed an effect on a compass needle in the neighborhood of a voltaic pile. Evidently, however the observation if made was very imperfect, as it led to no consistent recorded result. In this connection we must consider that the early years of the last century were disturbed by wars stirring the whole of Europe, and

further that the available voltaic currents must then have been relatively weak owing to the small area of battery plates used and to a high resistance of electrolyte. Strong acid could not be availed of as the zinc elements were not amalgamated, a procedure which was later almost universal. Again, the negative element was usually copper, giving against zinc a low voltage and subject to rapid polarization. There was, therefore, in the years before Oersted, little probability of such large currents being available or usual as would be needed when a single wire was used for the deflecting agency. This was, of course, before the principle of coiling the conductor to increase its effect was known. Dr. Robert Hare, the inventor of the oxyhydrogen or compound blowpipe, first appreciated, apparently in 1816, the need of increasing the surface of the zinc and copper to obtain, as it was afterward called, "large quantity." The blowpipe in his hands had become the most convenient source of heat of high temperature known to man, and the known heating effects of electric currents naturally led Hare to investigate means of intensifying them. He produced two forms of apparatus which were known as the Hare Calorimotor and the Hare Deflagrator. In the prior "trough" battery the plates were small, rarely more than four inches square, with one side only active. Hare rolled his zinc and copper sheets into interlaced spirals, spaced apart by wooden separators, so that not only large plates could be used, but both sides of the plates were active. Another form giving a similar result was embodied in the "deflagrator" which was used to deflagrate strips of thin metal in the same manner as the blowing of a modern safety fuse. In early youth it was the privilege of the writer to see examples of the apparatus of Hare which were preserved at the University of Pennsylvania then located in Philadelphia on the west side of Tenth St., between Chestnut and Market streets. Hare had been Professor of Chemistry there during the early years of the past century. The Hare apparatus is mentioned here because of a passage occurring in a work on Heat and Electricity printed in 1830. Its author, Thomas Thomson, M. D., was very eminent in the science of his time. The passage reads as follows: "The apparatus employed by Oersted, and of the efficacy of which he speaks in high terms, approached very nearly to this last one of Hare." This passage occurs just following a description of the "deflagrator". The statement seems to imply that Oersted early appreciated the value in a voltaic battery of large active surface, or as we should now say "low internal resistance." May it not be that this condition was the secret of his experimental success? Even in Franklin's time it had been observed that electric discharges had some obscure action on the magnetic needle, for sometimes compasses were demagnetized wholly or in part, or even reversed, when in proximity to a lightning stroke. Beccaria, the Italian contemporary of Franklin, tried many experiments with magnetized needles and heavy Leyden jar condenser discharges sent through them, but did not succeed in establishing any magnetic effect as due to the discharges. Such effects as he did obtain are readily interpretable at this time as the natural result of a vigorous shaking up, mechanical, or thermal, while the needle was in a magnetic field, such for example as that of the earth. Subsequently to Oersted's discovery, however, condenser discharges sent through a helix or spiral surrounding the needle were found to produce decided magnetic effects thereon.

The news of Oersted's discovery reached Paris, as it appears, through Arago, who had witnessed the experiments in Geneva on September 11, 1820, and on September 18th Andre Marie Ampère presented a paper to the Paris Academy of Sciences, remarkable for its originality and for the variety and accuracy of the experimental results recorded. In it he dealt with the interactions and repulsions of wires conveying currents and the magnetic effects of helices of wire, showing these latter to be possessed of magnetic poles. The fact that Ampère's paper appeared only a week after Oersted's discovery had become known to him, gives to it a unique place in the history of science. It was the production of a mind of the first order working at high pressure. Ampère was born at Lyons in 1775. As a child his precocity was most unusual. His tendency was toward mathematics, though his reading during youth brought to him a wide range of information in many branches of knowledge. The death of his father on the scaffold as a victim of political conditions almost wrecked his young life. Owing later to fortunate environment at a critical time, he gradually recovered, and in 1809, at thirty-four, was made Professor of Analysis at the Paris Polytechnic. The Oersted announcement evidently stirred him deeply and he went immediately to work with wonderful zeal and sagacity, to unravel the mysterious relationship between magnetism and currents, suggested only in part by Oersted's experiment. In his hands the fundamental character of these relationships became plain, and their future possibilities clear. It is recorded that he even suggested at the time the plan of a telegraph of simple form. As a side light, it appears that Ampère's discovery of the fact that parallel currents in the same direction in wires cause attraction, and when in the opposite direction repulsion, seems to have puzzled some of the philosophers of the time, for it was known of course that similar electricities repel and dissimilar attract. Why should not, therefore, similar currents repel and unlike attract, when in fact the exact opposite was the case? Ingenious, though altogether fallacious was an explanation first put forward and credited to Oersted. He was apparently driven to imagining that the current in wires did not go straight along the axis, but was conducted in a helical course in them always the same for the same direction of current. This was a pure invention without facts

to support it. But upon it he founded a theory of attraction and repulsion of parallel wires involving the old time attraction of unlike and repulsion of like electricities. In reality this theory bore with it its own refutation, as a few test experiments might easily have shown. In fact Barlow in England pointed out some of the contradictions involved in these ideas which had been elaborated by Ampère. In relation to this fanciful theory I find in the old book, before referred to as published in 1830, the following naive allusion—"This way of accounting for the phenomena of electromagnetism was first employed by Oersted. It was afterward used by others, particularly by Dr. Wollaston and M. Ampère with much felicity." The present writer does not vouch for the correctness of these statements. As soon, however, as the effects of currents in establishing magnetic circuits around them was worked out, the true cause of the attractions and repulsions of parallel wires became clear, and the fanciful notion of spiral courses for currents inside a conductor was abandoned. Such a notion has of course no relation to the later theory of Ampère for accounting for magnetism in iron or permanent magnets, in which he assumes each magnetic element to consist of a closed circuit with a current always circulating therein, a theory which to this day has not been displaced, but rather refined and strengthened by its further extension by Ewing and by the electron theory. It was in fact Ampère who referred all magnetism to electricity or electric currents, now interpreted as movement of electrons. The need of Ampère's clarification is perhaps made more evident from the following quotation, if it be a fact, "Oersted originally believed that the negative electricity propelled the north pole of the magnet, but had no effect on the south: while positive electricity propelled the south and had no effect on the north pole." The writer has not verified this statement as expressing the original ideas of Oersted, but if they at any time represented his view they must soon have been dispelled. They would be, perhaps, a sort of survival of older notions, at least in part, since before the "conjunctive wire" was used fruitless efforts had been made to connect magnetism and electricity while using batteries on open circuit. Ampère formulated a simple rule known as Ampère's rule, for determining the direction of deflection of a magnet or the direction of development of magnetism by a wire conveying current. It may be stated (bearing in mind that the direction of current, we assume, positive to negative, is merely a convention) about as follows: Conceive oneself lying or swimming in the current in such a way that the current enters by the feet and leaves by the head as we face the needle. Then the action will be that the north pole of the needle will turn to one's left. The writer must confess that when he first learned this rule it seemed rather clumsy to him, perhaps more so because he was sometimes treated to the ludicrous spectacle of an obese professor trying to twist himself with respect to an immovable wire circuit into curious attitudes so as to lie or swim in the current, and so note the direction of magnetism produced. Other ways of remembering the relation given by Ampère's rule have been devised, but perhaps none excel in ease and simplicity of application, a simple gesture of the hand, which has been used by the writer for about fifty years. The hand is held out with the index finger pointed away. If the hand be now given a swing or turn in righthanded direction, still keeping the forefinger directed as at first, such swing, turn, or rotation representing direction of current in a circuit, the north magnetic pole will be directed away as the forefinger points. Reversing the gesture, turning or swinging the hand counterclockwise makes the north pole take direction toward the wrist or forearm, or what is the same thing the extended forefinger represents the direction of south polarity. As the swing or slight rotation given the hand from the wrist and elbow represents all directions of current, above, below, and to the right or left of the magnetic axis considered, it is easy to select any element of current course matching actual conditions. Moreover, the same gesture (for it is simply a gesture, not a rule) applies equally to the relations of magnetic field developed around the course of a current, for if current passes in a wire in the direction of the point of the index finger, the magnetic circuit around it will have north polarity directed righthandedly, and lefthandedly or counterclockwise if the current has opposite direction; as from the tip of the index finger inward toward the wrist. In any case it is only necessary to make the simple gesture, which requires no especial mental effort. This soon becomes a matter of habit; a mistake being practically impossible.

According to de la Rive, Traite d'Electricite, Vol. 1, it was Arago who was first to show that a wire of copper or other metal acquired, when traversed by a strong current, the property of attracting and retaining around it, under the form of a cylindrical envelope, a quantity of iron filings; the filings falling off immediately when the current ceased to flow, and being reattracted on the restoration of the current. This experiment, prior to all those of Ampère, is the first which established in a striking manner that electric current impressed on conductors when it is transmitted by them, properties fully analogous to those of magnets, and not alone to magnetic bodies; in other terms, that it magnetizes them and does not simply render them susceptible of being magnetized. In fact, the iron filings are magnetized by the current as they would be by a magnet, and are in consequence attracted by the wire which transmits the current. This foregoing statement is substantially that of the account given by de la Rive, translated. Ampère and Davy are also credited with having made the

same observation, but if de la Rive is right, it was first made by Arago. But the statement is wrong; the wire is not made a magnet in the usual sense; the filings merely effect a better closure of the magnetic field lines around the wire than air does.

In this filings experiment was the first striking exemplification of the phenomenon of temporary magnetism in iron, so fundamental to the unlimited variety of electromagnets and mechanisms founded thereon; the basic principle of the Morse telegraph and most other signaling or electric recording systems and essential to the greater machinery of electrical engineering, developed for the most part in the latter half of the past century. Davy is credited with furnishing the proof that steel could be magnetized even at a considerable distance from the battery wire.

Arago went further and made his conducting wire into a spiral, and then succeeded in magnetizing steel needles placed in the axis thereof. In his pioneer experiments the spiral was wound open around a glass tube as a support, the wire itself being presumably bare. In Sillimans' Principle of Physics, (a well-known and much used text-book from its first edition in 1858, for perhaps thirty years thereafter) in describing the above experiment, there is the following statement: "If the helix is wound on a tube of glass, paper or wood, these substances offer no resistance to the passage of the power; but if a tube of copper or other metal were employed, the magnetizing power of the current on the enclosed bar would be destroyed." Such a statement means either that the metal tube short-circuited the bare wire of the helix or that currents of extremely brief duration, such as condenser discharges are concerned, or it is wrong as a statement of fact. It was indeed soon found that even "if common electricity be made to pass along the spiral conducting wire, the needle is equally converted into a magnet." Common electricity was evidently the frictional or static electricity thus distinguished from the then newer or less common voltaic current, later called dynamic electricity. The principle of coiling or increasing the turns on the original rectangular circuits of Oersted and Ampere was soon appreciated; even for deflection of needles. A hank of insulated wire wound around the hand or upon a rectangular block of wood as a mould and tied by string to preserve its form, was used to surround the needle; such a coil being the prototype of the taped coil of today. It seems to have taken some time to develop the coil consisting of a spool or bobbin wound closely with insulated wire. Schweigger used the rectangular coil of many turns in his "electric multiplier"; the term "multiplier" being extant for at least fifty years as applied to galvanometers with such coils.

The floating battery of de la Rive with either its "conjunctive wire", or with a spiral connecting the poles, was an exceedingly neat arrangement for showing the mutual action of currents and magnets, or the effects of wires conveying currents on others more or less parallel thereto. It seems to have been a very early modification of Oersted's and Ampere's apparatus. It avoided the problem of pivots conveying current, such as by mercury cups surrounding them. Ampere had considered a spiral conveying current as an actual magnet or as very similar thereto. It was soon found that iron or steel bars were drawn into the axis of spirals—the solenoid of today—and it is curious to note that Faraday disputed Ampere's conclusion by showing that a hollow magnet would only attract a needle by its outer surface and edges.

Arago's famous disk experiment, involving the discovery that a moving conducting disk of non-magnetic metal such as copper possessed an effect in the nature of a drag on a poised magnetic needle near it, was made about 1824. It was found also that if the needle was spun around over a conducting disk or plate, it was rapidly slowed or damped. These experiments were carried on by using a great variety of materials for the disk and wide variations in the magnitude of the effects were observed. Precautions were taken to eliminate any effects due to air currents. It was found that disks of the best conducting metal such as copper were the most effective. Here we have, then the prototype of eddy current dampers in magnetic fields. Curious hypotheses were advanced to account for the effects, such as the assumption of special forms of magnetism generated by revolution. In reality, had the secret of the action of the Arago disk been found, the generation of currents in a conductor moving in a magnetic field would have been discovered, and Faraday's discovery of that great principle in 1831 would have been anticipated by a number of years.

The full name of Arago was Francois Jean Dominique Arago, and he was a scientist of varied activities.

There is no space here to refer to his career except in the briefest possible way. Born in 1786 at Estagel near Perpignan, France, he displayed in his early years great aptitude for learning, and at eighteen became secretary to the Observatory of Paris, which brought him into contact with the famous La Place, and he was collaborator with Biot. He served in the determination of the meter as the unit of length; in measuring the ten-millionth of a quadrant of the earth's meridian. This task, involving travel into lands of turmoil, brought great dangers, imprisonment, escape in disguise, capture by the Spanish and prison again. Even after release he remained a long time in quarantine, on account of disease conditions. Given the post of astronomer in the Royal Observatory in Paris by Napoleon, in 1816, he started the famous Journal *Annales de Physique et de Chimie*. As Secretary of the Paris Academy of Science, Chief Director of the Observatory and as Member of the Chamber of Deputies, his life was a very full one, and its responsibilities heavy. He was associated with Fresnel in giving form to the undulatory theory of light proposing to test the theory by studying retardation in refractive media.

In fact his work on polarization of light, invention of the polariscope, and other researches rank scarcely less highly than his work in electromagnetism, with which we are here chiefly concerned.

The later discoveries by Faraday and his brilliant researches on electromagnetic rotations, and especially his discovery in 1831 of induction of currents by magnetism refined the early theories and added greatly to the development of electromagnetic science. Somewhat crude as the earlier ideas were, the clarification given them by Faraday, Maxwell, Kelvin and many others had the most profound effect on its future. As a direct outcome of Oersted's observations, mention may be made of the discovery in 1823 by Seebeck of thermoelectric currents in a closed circuit. He used a rectangle in a vertical plane surrounding a pivoted magnetic needle. The base of this closed circuit, so arranged, was a bar of antimony, while the ends and upper side were of copper. By heating one of the junctions of the antimony bar with the copper, deflection of the needle showed the presence of a current in the closed loop around the needle. This was followed by examination of the effects of junctions of different metals and conductors heated to various temperatures and led to the well-known table of thermoelectric powers. The thermo pile of Melloni, so delicate as a heat detector, was an outcome, and was used by him in his beautiful researches in diathermancy.

Having in the foregoing traced briefly the work of the pioneers in laying the foundation of the science a century ago, it is perhaps unnecessary to remind electricians and engineers of the great scientific advances and the important applications which soon followed. Some of them became familiar studies of the electrical student fifty years ago. This progress has continued and apparently at an increasing rate ever since.

To the consciousness of the writer the period of a hundred years seems continually to dwindle. He is reminded of the fact that his own life's span has covered more than two-thirds of a century. Looked at in this way, the Oersted, Ampere and Arago experiments do not seem to have been made, after all, so very long ago. Outside of forms of electromagnetic telegraph, the years following 1820 saw but few other applications of importance; but there were many examples of electromagnetic apparatus used for instruction in schools. The little book, now rare, entitled "Davis' Manual of Magnetism" was and is interesting as a catalogue, with brief descriptions, of such apparatus, some of which is doubtless still extant in the older collections. The first edition was publised in Boston in 1842, and the author, Daniel Davis, Jr., called himself "Magnetical Instrument Maker."

It may be interesting to quote the preface of this pioneer book as follows:

"Magnetism and electricity have become related sciences within so short a period, and their growth has been so rapid, that many important facts which have been observed have not yet been collected in any scientific treatise and the amount of unwritten knowledge has been constantly increasing. . . . . It will be found that many of the observations recorded here and many of the instruments described are new."

This statement was true enough, and for that reason, though it is a primitive production, the book has become almost a classic.

How many, or rather how few of us are left of those who as boys experimented with the sulphate of copper battery as their source of current, with flat spirals such as Henry employed, or with such apparatus as Oersted, Ampere and Arago used. We find in this little book of Davis' Henry's electromagnet, de la Rives floating battery, Faraday's revolving circuits and magnets, Barlow's spur wheel, Page's revolving ring, his revolving magnet and revolving multiplier, and other examples of the simplest type of electric motors with commutator and brushes called "pole changers," and even apparatus with both commutator, revolving brushes, and slip rings, so that both elements of the motor might revolve oppositely. There were bell engines, so-called, and reciprocating engines, elementary motors driven by thermoelectric currents, or by batteries revolving, all involving the simple principles of interaction of circuits and magnets, permanent or temporary. These and other simple forms of apparatus, besides the older devices for "static" electricity, were the things electrical with which the youngster with an electrical bent became familiar, either in his reading, or better, by the fascination of experiment with them. Such equipment characterized the infant years of the science; now grown to a giant with no limit to future growth.

It was natural that the first great practical application of electromagnetic principles should be found in the telegraph.

Attempts have been made as early as 1774 to telegraph by the electricity of frictional machines, which even as late as 1850 was called "machine electricity" or "common electricity from machines." Even in 1816 Ronalds in England was attempting to signal through long circuits by Leyden jar discharges. After the discovery of the voltaic pile in 1800 there was a better prospect of success, and Sömmering in 1808 proposed a system of 35 wires at the ends of which were gold strips in water, upon which strips gas appeared on the passage of current, which appearance constituted the signal received. There was a wire so arranged for each letter or character transmitted. It was Ampere, who, just after Oersted's discovery, proposed to substitute in Sömmering's system deflected needles for the voltmeter receivers. Then followed Schilling in Russia in 1832; Gauss and Weber at Gottingen in 1833, and finally Cooke and Wheatstone in England and Steinheil in Munich in 1837, to whom perhaps more than to any others the development of the needle telegraph for practical work was really due.

The Morse type of telegraph was early distinguished as the electromagnetic telegraph, or one based on the use of electromagnets. Barlow in England seems to

have made an early suggestion of the kind, but it was not until 1830, upon the construction of the first powerful electromagnets by Joseph Henry of Princeton, New Jersey, that such a form became possible. In his first paper on the results of his experiments, Henry proposes to apply them to the telegraph. Samuel F. B. Morse conceived of such a telegraph in 1832, and with the assistance of Vail worked it out practically; and publicly exhibited the Morse system working over a circuit of a third of a mile in 1837, but after that it was nearly seven long years before Congress for consideration, when at last a modest grant was made to establish the famous Baltimore-Washington line first put into operation in 1844.

In the subsequent numerous developments of systems of signaling from the simple call bell to the fire alarm and printing telegraph, the electromagnet holds undisputed sway. In annunciators of many types it is found, as often with polarized cores in relays and in telephone receivers and the like; indispensable in wireless transmission as in transmission by wires. The extreme sensibility of the telephone receiver, coupled with the wonderful delicacy of the ear, makes it most effective for the detection of minute electrical disturbances. With modern themionic amplifiers the possible extension in range of telephonic transmission by wireless waves seems to be without limit.

It is not necessary here to allude to the great developments in the field of electricity and electromagnetism as exemplified in generation and transmission of electrical energy. They have covered the past half century, but the foundation principles belong to those early years of upward of a century ago. Do we cause movement of iron masses by a current coil? It is the experiment of Oersted. Do we cause movement of coils, one with relation to another, as in our motors? It is the experiment of Ampère. Do we generate currents in a conducting mass in a magnetic field? It is the experiment of the Arago disk. When we measure current or energy by galvanometer, voltmeter, electrodynamometer, or wattmeter we have the work of Oersted, Ampère, Arago and Davy illustrated. But these early discoveries had a deeper significance still. They showed that electric currents and magnetism are inseparable—inseparable in practise, inseparable in theory. Moving charges are, as shown by Rowland, the equivalent of currents; and now we are assured that moving charges and currents are moving electrons. Hence moving electrons are magnetic. Like charges or electrons repel each other, but like charges moving in the same general direction attract, for they are the equivalent of parallel currents in the same direction. They repel one another electrostatically and attract one another magnetically. Conversely, oppositely moving charges or electrons should repel, and also continue to repel electrostatically. We are now certainly down to the fundamentals. No vacuum, however perfect, lessens or stops the development of the electric field in it, nor prevents the existence of the magnetic field. Space itself is electromagnetic, using the term in its broadest sense. Like electrons moving in the same direction in such space must attract one another and at some speed the static repulsion of the like charges will be balanced by this attraction. The higher the speed, the closer is the approach, until the repulsion balances the attraction. And just here is the key to the phenomenon of nature. Space, whether empty or full of ether, is fundamentally electromagnetic and perhaps only that. Energy and mass, interchangeable terms and due to relative movements of electrons are electromagnetic and only that. Matter in all its forms, systems of electrons in motion, is an electromagnetic organism. Alive or dead it is electromagnetic and nothing else. All properties of matter, all forms of energy are electromagnetic and electrostatic. If ether exists it is purely and solely electric and magnetic, without mechanical properties, for such properties depend on motion of electrons. Ether as a medium, then, not being mechanical, can neither be in rest nor in motion; it can only be the theatre of electrostatic and magnetic conditions, whatever that may be. The term "space" is as good a one as "ether." These statements may be very sweeping, but do not the recent notions of relativity of Einstein carry us even farther? Space is empty, but has a warp in it; it is curved and of four dimensions, one being time, in which the gravitational field of the sun, or for that matter even the smallest speck of matter or energy is largely a local warping. Are electric and magnetic fields but other kinds of warping in this space, which though empty is full of electric, magnetic, and gravitational fields? Whatever all this may mean, we must remember that scientific theories can never change the facts; they are not creeds, they are means of pointing the way to further additions to our knowledge—to be modified, changed or abandoned according to their usefulness in leading to further knowledge or discovery. The facts of science are its bed-rock foundation, unchanged and unchanging. The discovery, then, of the relation between electricity and magnetism was in reality the discovery of a fundamental fact or principle lying at the foundation of the universe itself; the soul of energy, as also of matter, of electric waves from zero periodicity up to the most penetrating rays of the radium emanations. It is eminently fitting, then, that we celebrate the hundredth anniversary of discoveries, the fruits of which have been of stupendous influence and value, and at the same time carry us to the very foundations of existence; but we meet also to do honor to the great men who first brought those discoveries to light.

The coming century will doubtless have its wonders to unfold, but it is fairly safe to predict that they can hardly exceed in fundamental bearing those revealed to us in the past hundred years.

Oersted's and Ampère's Discoveries

BY M. I. PUPIN

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THE names of Oersted and Ampère always recall to my mind the names of several other great men of science who with Oersted and Ampère form a group of intellectual giants. Their pioneer discoveries produced the science of physics and engineering of today. The names of the members of this immortal group are: Copernicus, Kepler, Galileo, Newton, Oersted, Ampère, Faraday and Maxwell. Their discoveries follow each other in evolutionary sequence during an interval of over four centuries, and each one of these discoveries is a link in the chain of evolution of our physical concepts concerning the most fundamental physical phenomena, the phenomena of motion of matter and of electricity. I trust, therefore, that I will be pardoned when on this occasion, the Centennial Celebration of Oersted's and Ampère's discoveries, I indulge in a brief review of the discoveries of the other great scientists who with Oersted and Ampère share in the glory of creating the modern science of dynamics, including electrodynamics.

Prior to Copernicus the science of statics flourished. The interest of the inquiring mind was centered in the study of the conditions of equilibrium, the conditions of rest. The philosophy of Ptolomeus taught man that the earth was at rest and that the universe revolved around it. But a few years after Columbus announced his discovery of a new continent, Copernicus, a great Slavonic astronomer, announced his discovery of a new universe, the universe, namely, in which the planets revolve in circles around the sun, the central body. The earth was no longer a body at rest, a sort of sleepy hollow in the center of a busy universe; it became a most active celestial body, rotating about a fixed axis and moving with enormous velocities in its great orbit around the sun. This great revelation gave a powerful impulse to the inquiring mind of man to turn its attention to the science of motion. A hundred years later, at the time when the Pilgrim fathers landed at Plymouth Rock, Kepler, a great Austrian astronomer, amended the teachings of Copernicus by constructing from Tyho Brahe's astronomical observations his three laws of planetary motions. The Copernican system no longer appeared then as a mere geometrical scheme to describe approximately celestial motions, but it forced the suggestion upon the human mind that there must be a dynamical background to the planetary motions, and, of course, to all motions of matter. Kepler and his contemporaries, although aware of the existence of this dynamical background, could not answer the questions, why the planets move around the sun in elliptical orbits, the sun occupying one of the foci of these orbits? Why the radius vector from a planet to the sun sweeps over equal areas in equal times? And, finally, why the squares of the planetary periods of revolution around the sun are in the same ratio to each other as the cubes of their mean distances from the sun? Galileo, a contemporary of Kepler, was the first to recognize that an answer to these questions cannot be given until we find a correct answer to the older question, the question, namely, why bodies fall to the earth. "Horror vacui" was given as the cause by the scholastics of the Middle Ages. That explanation was just as trivial to Galileo as Aristotle's statement, that bodies fall to the earth because they seek their proper place. Galileo had perfected the telescope and by its aid he discovered the satellites of Jupiter. One cannot help thinking that the orbital motions of these satellites as they appeared to Galileo must have reminded him of the oscillations of Benvennto Cellini's beautiful bronze lamp in the Cathedral of Pisa, which he observed when still a mere youth, and that these periodic motions are closely connected to the motions of a falling body. His experiments with bodies falling from the leaning tower of Pisa shed light upon these problems which stirred Galileo's imagination and they began to clear up the mystery which prevented man from seeing the simple relation which exists between force and the motion produced by it. We may say that Galileo was the first to detect by these experiments at Pisa the existence of a new quantity, namely the momentum of moving mass and the law that the time rate of variation of this momentum is equal to the moving force. No mortal man ever began to clear up a deeper mystery and Lagrange is right when he says that none of Galileo's wonderful discoveries in astronomy displayed Galileo's genius so strikingly as his discovery of the remarkably simple law of motion of a falling body. The world was ready then to catch a glimpse of the true meaning of the dynamical background of Kepler's laws of planetary motion, but nevertheless it took a century before Newton raised upon the foundation prepared by Kepler and Galileo the complete structure of dynamics of moving matter and illustrated its great power by employing it in his demonstration of the existence of universal gravitation and of the law of action of gravitational forces.

This, broadly stated, is the evolutionary development of our knowledge of matter in motion. A strikingly similar evolutionary development took place in our knowledge of electricity in motion. What Copernicus, Kepler, Galileo, and Newton achieved for our

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knowledge of matter in motion, that was achieved by Oersted, Ampère, Faraday and Maxwell for our knowledge of electricity in motion. Oersted is the Copernicus, Ampère is the Kepler, Faraday is the Galileo, and Maxwell is the Newton of the science of electrodynamics, the science of electricity in motion.

This science dates from the beginning of the eighteenth century, when Stephen Gray, a contemporary of Newton, discovered that certain bodies conducted the electrical virtue, as he sometimes called the electrical charge. If conductors did not exist the science of electrical engineering would not exist today, and the science of electricity would probably be in the same state today in which it was prior to the time of Gray. Gray's discovery is, therefore, one of the foundation stones of the science, and it was the first stimulus which excited man's interest in the phenomena of motion of electricity. That interest was very much amplified when Franklin showed that lightning was an electrical discharge, similar to the discharge of a Leyden jar or a Franklin plate. When, finally, at the end of the eighteenth century Galvani and Volta showed how to make a generator of electrical motions which far surpassed both in power and simplicity of construction anything which had been done before, then the science of electrical motion began to develop by leaps and bounds.

The science of the electrical current enters the nineteenth century with Sir Humphry Davy's brilliant experiments with the electrical arc, the melting and the electrolytic power of the electrical current. Sir Humphry Davy did not discover the electrical arc, nor electrolysis, nor the heating power of the electrical current, but his experiments were so surpassingly striking that they gave a new and most powerful impulse to the inquiring mind to search for new physical effects in connection with these wonders produced by electricity in motion.

Oersted was in close touch with Davy's experiments and probably learned from them how to make powerful voltaic generators. The legend exists that Oersted discovered by accident the magnetic force exerted by electricity in motion. Even if the legend were true it would not diminish by one iota Oersted's glory, because history shows that he was in closest touch with the most recent advances of the science; it is there that wonderful accidents always occur to wonderful men. The existence of this legend is undoubtedly due to the fact that no electrical phenomena known to the physicist prior to Oersted's discovery in 1820 would lead one to expect that electricity in motion was capable of producing the magnetic force disovered by Oersted. Heating and electrolysis were local effects produced by moving electricity; they occurred there where the motion actually took place. But the magnetic force discovered by Oersted was not local; it was felt everywhere, in places where no electrical motion of any kind was observable. Ampère's wonderful analysis showed that the circuit carrying an electrical current was a magnet; and it culminated in his great law which determines the magnetic field in terms of the distribution of the electrical currents producing that field. Ampère's contribution to Oersted's discovery is similar to the contribution which the Copernican discovery received when Kepler first announced his three laws of planetary motions; but whereas a century elapsed between Copernicus and Kepler only a week elapsed between the time when Ampère first learned of Oersted's discovery, and Ampère's announcement of his fundamental law of electromagnetism.

Copernicus and Kepler sowed the seed, the fruition of which took place in the brains of Galileo and Newton; that was the great glory of Copernicus and Kepler. Similarly, Oersted and Ampère sowed the seed, the fruition of which took place in the great brains of Faraday and Maxwell, and just as Copernicus and Kepler had prepared the foundation upon which Galileo and Newton raised the structure of the science of dynamics of matter in motion, so Oersted and Ampère prepared the foundation upon which Faraday and Maxwell raised the structure of the science of dynamics of electricity in motion. The evolution of scientific concepts which carries us from Copernicus and Kepler to Galileo and Newton is the same as the evolution of scientific concepts which carries us from Oersted and Ampère to Faraday and Maxwell.

It was first pointed out by Helmholtz and Thomson that the principle of conservation of energy properly understood and applied to the discoveries of Oersted and Ampère leads directly to the inference that variable magnetic fields should produce electrical forces; in other words, the existence of electrical fields produced by varying magnetic fields might have been predicted by pure reasoning even without Faraday's classical experimental researches and discoveries. But in my opinion, it is most fortunate that the principle of energy was not understood at the time of Oersted and Ampère, and that the world needed a Faraday to discover what some other man, much smaller than Faraday, might have predicted from Oersted's and Ampère's discoveries by means of the energy principle.

It was Arago who brought Faraday into the field of research which Oersted and Ampère had just created. The science of electrodynamics owes a great debt to Arago, not only because he was the first to bring to Ampère the first accurate account of Oersted's discovery, but also because soon after that memorable date he discovered a great puzzle for the physicists of the world, the puzzle, namely, of explaining why the oscillations of a magnetic needle are damped out by a conductor in its vicinity, and why a conductor rotating in the vicinity of a magnetic needle will drag the needle with it? That explanation was destined to inaugurate a new movement in the evolution of ideas concerning electrical motions similar to the evolutionary development of scientific ideas inaugurated by Galileo's experiments at Pisa. It was first given by Faraday when in 1831

he discovered electromagnetic induction. Maxwell was born in the same year in which this great discovery was made, the first in the long series of Faraday's fundamental discoveries. Thirty-four years later he interpreted the full meaning of Faraday's discoveries in a manner which reminds one of Newton's interpretation of Galileo's experiments at Pisa.

Continental physicists did not understand the new mode of expression of Faraday, the son of a blacksmith who started his scientific career as an humble assistant in the chemical laboratory of Sir Humphry Davy. He was a man without academic training and without a knowledge of the mathematical language which was then employed by the foremost continental physicists. His experimental discoveries won the unbounded admiration of the world, just as Galileo's astronomical discoveries did, but Faraday as a prophet who had a great scientific message to deliver to the physicists was not understood nor appreciated. Neither was Galileo. Faraday's disciple and apostle, immortal Maxwell, was more successful, but even his contemporaries were not certain that they quite understood his full meaning. Voltaire says that forty years after the publication of Newton's Principia there were no more than twenty men outside of England who followed him.

What, then, was the new message which Faraday and Maxwell delivered to electrical science of their time?

Faraday's discovery of electromagnetic induction made it clear to Faraday himself that the magnetic field discovered by Oersted and analyzed by Ampère represents a state controlled by the electrical motions which produced it, and that the variation of that state in any part of space gives rise to the electrical forces which react against that variation. Faraday called that state the electrotonic state, but he considered it as a mere suggestion because he never succeeded to define it quantitatively and to connect it in a definite manner to induced electrical forces. But in 1855 a mere lad of 24, Clerk Maxwell, who had just been graduated from the University of Cambridge announced that Faraday's electrotonic state is nothing else than the electromagnetic momentum of the magnetic field. The momentum of a moving body is its life and Galileo was the first to detect its existence. Similarly the momentum of moving electricity is its life and Faraday was the first to detect its existence. But there is, as you know, a fundamental difference between Galileo's momentum and Faraday's momentum. The first is localized in the moving material body, the second is not localized in the moving electricity, but is distributed over the whole space wherever the magnetic force of the electrical current is felt. This space distribution of the electromagnetic momentum fascinated the lively imagination of young Maxwell to such an extent that he spent many magnificent efforts in order to explain it by mechanical models. The value of these models is historical; they do not enter into Maxwell's final ormulation of the fundamental laws of electrodynamics which may be stated as follows:

Draw a closed curve, a circuit, in any part of space and consider the magnetic flux which is interlinked with that circuit. The electromagnetic momentum of the magnetic field with respect to that circuit is equal to these flux interlinkages, and its time rate of variation is equal to the electromotive reaction of the circuit, the reaction opposing this change of the electromagnetic momentum. This is one of the fundamental laws of Faraday-Maxwell's electrodynamics. When stated in the above form its formal resemblance to Newton's second law of motion is most striking.

The second law of Maxwell's electrodynamics is a bold extension of Ampère's law of electromagnetism. Maxwell first pointed out that Ampère's law of electromagnetism can be stated as follows: The magnetomotive force around any closed curve, or circuit, in the magnetic field produced by electrical currents is equal to 4π multiplied by the electric current which flows through any surface bounded by that curve. This state ment of the law differs in form from that of Ampère, but it is equivalent to it. But whereas Ampère referred to electrical currents which represents motion of electricity in conductors, Faraday and Maxwell centered their attention not so much upon electrical charges as upon the tubes of force which they associated with them, 4π tubes per unit charge. Maxwell's hypothesis was that wherever these tubes vary there is an electrical current producing the same magnetic effects as the electrical conduction current studied by Oersted and Ampère. This hypothesis enabled Maxwell to formulate the second fundamental law of electrodynamics in a general way as follows:

Draw a closed curve in any part of space and consider the electric flux which is interlinked with that curve. The magnetomotive force around the closed curve is equal to the time rate of variation of this electrical flux.

The formal resemblance between these two fundamental laws of electrodynamics as Maxwell formulated them is certainly remarkable. The foundation of the first was discovered by Faraday, that of the second was the discovery of Oersted and Ampère, but the amplification of these foundations and the complete structure raised upon them is the work of Maxwell, the Newton of modern electrodynamics.

When Newton completed his formulation of the laws of motion of matter he was ready to reveal to mankind his discovery of the law of gravitation. When Maxwell completed his laws of motion of the electromagnetic flux he was ready to reveal to mankind a discovery which to Faraday appeared as a mere dream, but which to Maxwell was a reality. The discovery was the electromagnetic nature of light. Maxwell's two fundamental laws in electrodynamics lead directly to the result that electromagnetic dis-

turbances are propagated through various media with the same velocity and in the same manner as light, and since we can predicate the same things for the propagation of one as for the propagation of the other we are justified to consider the two as identical. This is what Maxwell did and when he did it the great electromagnetic theory of light was born.

This was the message which Faraday and Maxwell had to deliver to the world. Faraday began to formulate his message when he discovered the magnetic rotation of the plane of polarization of a beam of light; he went a step further in his historical discourse on "Thoughts on Ray Vibrations." Maxwell delivered the message but the world needed over thirty years to grasp its full meaning. Hertz's classical experiments of 1887 were the first to reveal and to illustrate this meaning to the unbelieving world.

Maxwell's Electromagnetic Theory founded upon the work of Oersted, Ampère, and Faraday was meant to embrace the phenomena of electricity in motion and the phenomena of light. Recent advances in electron-physics and in radiation justify the hope that Maxwell's Electromagnetic Theory will lead to a more complete knowledge of the constitution of matter than man ever dreamt of prior to Oersted's and Ampère's discoveries.

The Centennial of the Discoveries of Oersted, Arago, and Ampère

BY C. E. MAGNUSSON

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IT is eminently fitting that the Pacific Coast members of the Institute, in convention assembled, should pause in their labors on present day problems and consider the significance of this day and year as the hundredth anniversary of the fundamental discoveries of Oersted, Arago, and Ampère. One hundred years ago today, the 21st of July, 1820, Oersted announced his notable discovery of the directive effect of the electric current on the magnetic needle; this year is likewise the centennial of Ampère's brilliant achievement in determining the laws of electrodynamics.

With present day knowledge of electric phenomena, the basic importance of Oersted's and Ampère's discoveries is readily understood, but in order to appreciate the magnitude of their achievements, it is necessary to have a sympathetic understanding of their environment, to keep in mind the prevalent scientific theories and the views of their contemporaries, and to realize how little was known of electric and magnetic phenomena. To reach this point of vantage requires effort—particularly for electrical engineers. We give little thought to what happened yesterday. Our minds dwell on coming events. Out watchword is "What is new?" Our interest lies at the front, and we eagerly discuss the latest advances in the electrical field. What was discussed last year is now an old story. It is surprising how seldom we find it necessary to look back even ten years in our technical journals. Verily, the electrical engineer lives in the future.

In order to more readily sense the "atmosphere" in which investigators in the electrical field labored in 1820, and to better perceive the frontier of scientific knowledge, the dividing line between the known and the unknown, it may be advisable to briefly call attention to some of the salient points—a few landmarks in the scientific world of their day.

Europe was slowly recovering from the devastations of the Napoleonic Wars, which had closed with the battle of Waterloo in 1815. After a century of diplomatic intrigue, misgovernment and revolution, Europe had entered upon a period of material and intellectual development. The use of steam was rapidly increasing in importance as an industrial factor. Watt had finished his labors; Fulton had successfully applied steam to navigation (1807); and Stephenson had invented the locomotive (1814); but the first steam railway was not built until 1830. The caloric theory of heat still held sway, although Rumford, Young, and Davy (1812), had already proved experimentally that "the immediate cause of heat is motion, and that the laws of its communication are precisely the same as the laws of motion." The controversy between the partisans of the emission and undulatory theories of light was at its heighth, with Biot, Poisson and Laplace championing the former and Fresnel, Arago and Young the latter. The atomic theory and Dalton's law of multiple proportions had been firmly established by the comprehensive and extraordinarily accurate determinations of the atomic weights by Berzelius. In 1807 Davy had decomposed the alkaline salts by electrolysis and produced metallic sodium and potassium.

Although magnetic and electrostatic phenomena had received much attention during the 18th century, the known facts were few and isolated. In a notable series of experiments, using the torsion balance,

*Address delivered at the Pacific Coast Convention of the A. I. E. E. Portland, Oregon, July 21, 1920.

Coulomb had determined the laws governing the action between electrostatically charged spheres; and in 1790 Galvani had observed the physiological effect of contact voltage as indicated by muscular contraction. It was, however, not until 1800 that Allessandro Volta invented the voltaic pile, and thus provided a means for producing galvanic electricity or electric currents. Although large primary batteries of copper-zinc elements with dilute solutions of sulphuric and nitric acids as electrolytes were constructed and used by many physicists, it took twenty years before the next milepost of progress in the electromagnetic field was erected. Early in the year of 1820, Johannis Christianus Oersted[1], Professor of Natural Sciences, University of Copenhagen, observed, while lecturing on electricity, galvanism and magnetism, the motive effect of a galvanic current on a nearby magnetic needle. For several months he conducted an extensive series of experiments to determine the laws of the observed phenomena. Realizing the importance of his discovery, he described the experiments in a carefully prepared report, and stated in concise form the laws governing the conflict between galvanic electricity and the magnetic needle. The pamphlet written in Latin and entitled, "Experimenta Circa Effectum Conflictus Electrici In Acum Magnetican," was published on the 21st day of July, one hundred years ago today. The essential part of Oersted's discovery can best be given by a quatotion from his original announcement.[2]

The opposite ends of the galvanic battery were joined by a metallic wire, which, for shortness sake, we shall call the uniting conductor, or the uniting wire. To the effect which takes place in this conductor and in the surrounding space, we shall give the name of the conflict of electricity.

Let the straight part of this wire be placed horizontally above the magnetic needle, properly suspended, and parallel to it. If necessary, the uniting wire is bent so as to assume a proper position for the experiment. Things being in this state, the needle will be moved, and the end of it next the negative side of the battery will go westward.

The uniting wire may change its place, either towards the east or west, provided it continue parallel to the needle, without any other change of the effect than in respect to its quantity. Hence the effect cannot be ascribed to attraction; for the same pole of the magnetic needle, which approaches the uniting wire, while placed on its east side, ought to recede from it when on the west side, if these declinations depended on attractions and repulsions. The uniting conductor may consist of several wires, or metallic ribbons, connected together. The nature of the metal does not alter the effect, but merely the quantity. Wires of platinum, gold, silver, brass, iron, ribbons of lead and tin, a mass of mercury, were employed with equal success. The conductor does not lose its effect, though interrupted by water, unless the interruption amounts to several inches in length.

The effect of the uniting wire passes to the needle through glass, metals, wood, water, resin, stoneware, stones; for it is not taken away by interposing plates of glass, metal, or wood. Even glass, metal, and wood, interposed at once, do not destroy, and indeed scarcely diminish the effect. The disk of the electrophorous, plates of porphyry, a stoneware vessel, even filled with water, were interposed with the same result. We found the effects unchanged when the needle was included in a brass box filled with water. It is needless to observe that the transmission of effects through all these matters has never before been observed in electricity and galvanism. The effects, therefore, which take place in the conflict of electricity are very different from the effects of either of the electricities.

If the uniting wire be placed in a horizontal plane under the magnetic needle, all the effects are the same as when it is above the needle, only they are in an opposite direction; for the pole of the magnetic needle next the negative end of the battery declines to the east.

That these facts may be the more easily retained, we may use this formula—the pole *above* which the *negative* electricity enters is turned to the *west*; *under* which, to the *east*.

It is difficult in our day to appreciate how strange and unaccountable the phenomena appeared to Oersted and his contemporaries. Not until eleven years later did Faraday make his epoch-making discovery of electromagnetic induction and give "chart and compass" to explorers on the electromagneto-dielectric main, by his conception of the now indispensable magnetic and dielectric lines of force. We are so accustomed to use the lines of force when thinking of electromagnetic phenomena that without this concept we are entirely at sea. Conceive, if you can, some rational explanation of the strange action of the magnetic needle in the presence of a conductor carrying an electric current without using Faraday's concept of magnetic lines of force.

The news of Oersted's discovery was brought from Geneva to Paris by the celebrated physicist Dominique Francois Jean Arago, who repeated the experiments before the French Academy on September, 11th. Among the savants present at this meeting was Andre Marie Ampère, professor of Analysis in the Polytechnic Institute in Paris. Seven days later Ampère presented a most remarkable paper before the Academy, announcing new discoveries of far reaching importance. He described a series of ingeniously devised experiments showing the action of one electric current upon another, and formulated the fundamental laws of electrodynamics. Two parallel and like directed currents attract each other, and two parallel electric currents flowing in the opposite direction repel each other. He proposed the elegant molecular electric currents theory as an explanation of magnetic phenomena and the interaction of electric currents with the magnetic needle. For many years physicists had looked for an explanation of electricity as a form of magnetism, but Ampère showed that, contrary to expectations, magnetism was due to electric currents. In the same paper he gave a remarkable mathematical analysis of the observed phenomena, which offered a theoretical explanation of the interconnection between magnetism and electric currents.

In one short week Ampère had accomplished more than all his predecessors and laid a firm foundation

1. In Danish, Hans Christian Orsted.
2. English Translation, Annals of Philosophy, Vol. XVI., p.274, London, 1820.

for extensive developments in the electric field. Whether we consider the clearness and convincing power of his mathematical analysis, the ingenuity and skill displayed in the experiments, the elegance of his molecular electric current theory, or the marvelous rapidity with which the work was accomplished, Ampère's achievement is of the highest order.

A few days later Arago observed that iron filings cling to a wire carrying an electric current but drop off when the circuit is broken. Arago and Ampère working together showed that a helix of wire carrying an electric current around a bar of iron or steel would make the bar strongly magnetic. Thus the modern electromagnet was invented. These discoveries of Oersted, Ampère and Arago advanced the knowledge of the laws governing electric circuits far ahead of what was known of magnetism and static electricity.

In commemorating the centennial of a scientific discovery, our interest necessarily centers on the phenomena observed, the theories advanced, and the importance of the laws established. In contemplating these discoveries, one is filled with admiration over the originality and clarity of thought, the initiative, and the constructive imagination of the investigators. However, acceptable homage is not paid by adulation but by an ardent desire to help in extending the realm of human knowledge. The centennial celebration of great scientific discoveries should add to our zeal and be an inspiration to all workers in the vineyard.

The conditions for scientific research today are very favorable as compared to a century ago. The available funds are enormously greater, the equipment better, and an army of workers is now engaged in extending human knowledge in place of a few knight-errants of old. The economic importance of research in the manufacturing industries is the mainspring for most of the support, but even pure research is progressing on a scale hitherto unknown. The relative importance of the universities and industrial research laboratories as centers of scientific thought and intellectual progress is indicated by the importance of the discoveries made and the number of notable papers presented before the learned societies. The most favorable conditions in practically all fields are now found in the United States, a fact which presages future leadership for our country in intellectual achievements.

But if we take a smaller division and consider the conditions on the Pacific Coast, which is of special interest to us, the situation is far from flattering. The amount of research in progress in the Golden West is a negligible quantity as compared to that of the whole United States. The material aids to research, funds and apparatus, are distressingly inadequate for the successful prosecution of research, and the young men of initiative and research talent go east to the well-equipped laboratories of industrial plants and research foundations. The quickening power of research to manufacturing is not appreciated by western captains of industry, and the huge enrollments of undergraduate students in our universities is a handicap to productive scholarship in our seats of learning.

But the West is the land of promise. Here the scientific investigators, the creative thinkers must carry on and realize the dreams of the pioneers. The discoveries of Oersted, Arago and Ampère, the wisdom and knowledge of the ages, are our heritage; the unlimited possibilities of the future, our opportunity.

MUNICIPAL PLANT OPERATED BY PRIVATE INTERESTS

Private operation of a municipally owned plant is rather a rare combination. It is being tried out in Alameda, California, as a result of the power shortage in that state. Recently the Alameda Municipal Power Plant closed down and its machinery was packed in oil and waste to prevent deterioration, the municipality having found that it could purchase power much more cheaply from the Great Western Power Company than it could be produced with fuel oil at its present high price. During the last few weeks the power shortage has become so acute that the power companies of that section, in order to fulfil their contracts, sought to have the municipality of Alameda resume generating its own power temporarily. This it refused to do, but did agree to operate its power plant with its own employees and use the current so generated, turning over to the Pacific Gas and Electric Company, for use elsewhere, the current the city was securing from the Great Western Power Company. Alameda continues to pay the Great Western Power Company for power, while the Pacific Gas and Electric Company is paying the cost of putting the Alameda municipal plant back in service, and all costs of operation, and, when the present emergency has passed, will pay the cost of putting the plant out of service. This evidences two things: First, that the central station, when necessary, will do everything in its power to supply service to its customer; and second, that another municipality has definitely abandoned its municipal light and power plant, even though that plant is in excellent condition.—*N. E. L. A. Bulletin.*

The Electric Melting Furnace

The Early History of the Electric Melting Furnace and its Development into Various Commercial Types.

HISTORY OF THE ELECTRIC FURNACE

BY JOSEPH W. RICHARDS
Professor of Metallurgy in Lehigh University

What I am going to tell you is not new, but it will supply a background for the following papers by stating some of the historical relations in the development of the electric furnace.

About 1877 Siemens got the idea that it would be possible to melt steel commercially by the use of the electric arc. He spent a great deal of money and exercised a good deal of ingenuity in trying to melt steel in a crucible by means of the electric current. He tried this in two ways: First of all to melt the steel by radiation from an arc, and second by making the steel one pole of an arc.

He took a crucible, bored holes in the sides near the top, put electrodes through these holes, placed the metal in the bottom and a lid on top and then started an arc, melting the steel by radiation. That was the first arc-radiation furnace.

He also took a crucible, using but one electrode passing through the lid and making the steel itself one of the electrodes of the arc. The upper electrode was comparatively easy to design, but the lower electrode (to take the current away from the steel itself) was the cause of trouble. He bored a hole through the bottom of the crucible, reinforced it outside by a block of concrete, and screwed in a sort of a plug of soft iron. He relied upon this for carrying away the current, it being in contact with the melted steel inside and cooled by the air outside. His proposition attracted much attention. In some cases he obtained a thermal efficiency as high as 50 per cent.

He tried to make this furnace run commercially, but it did not prove effective due to the uncertain nature of the iron connection through the bottom. He spent a great deal of money trying to make it a commercial success, but was unable to do so. He did, however, get some fairly high thermal efficiencies, but his apparatus was not good enough for commercial use. That sums up in a few words what Siemens tried to do and what he accomplished.

The next to experiment with the electric furnace to melt steel by radiation from the arc was Captain Stassano of the Italian Army. He built a furnace four feet in diameter and three feet high, with three electrodes passing in through the upper parts of the walls, coming together in triangular formation above the bath, and using a three-phase arc. The furnace was capable of holding about a ton of steel. It was used commercially in Turin, Italy. Because of the cheapness of power—\$12.00 per h.p.-yr.—and with scrap steel at about \$5.00 per ton, he was able to charge his furnace, melt down the steel, pour it into castings, and successfully compete with the steel made in open-hearth furnaces or in Bessemer converters. This was a direct development of Siemens' idea—melting by radiation from an arc. From forty to fifty furnaces of this type are at present in operation throughout the world.

There are other furnaces of a somewhat similar character, heated by radiation from the arc. Sometimes the arc is changed a little in shape. Such a one is the Rennerfelt furnace, which is essentially of the same general type, though differing in details. It consists of two horizontal and one vertical electrodes, which project the arc like a blowpipe on the surface of the metal.

There are still other types of the arc furnace. There is the rocking arc-furnace, in which the electrodes pass through the sides of the furnace, but the metal is rocked so that it is uniformly heated, thus combatting unevenness of temperature caused by intense heating near to the arc. This particular modification of the arc-radiation furnace has been found very useful in the melting of alloys containing volatile metals, such as, particularly, brass.

The other type of furnace devised by Siemens, with the arc passing from the electrode to the metal, is known as the arc-resistance furnace. In such furnaces the larger part of the energy which melts the metal is generated in the arc. This idea was first worked commercially by Girod, a Swiss electrical engineer, who conceived the idea of taking a regular saucer-shaped, steel-melting hearth and putting through the bottom of it a large hole, through which was inserted a soft, low-carbon steel rod. The electrode passing through the hearth was eighteen inches long; in running it melted six inches and left twelve inches solid. This automatically sealed it, and the current was taken away from the projecting end outside, which was water-cooled. One or more of these heavy electrodes was arranged in parallel through the bottom of the hearth. Ten, twelve, and even twenty-ton furnaces are in operation on this design. All grades of steel are successfully made in these furnaces. The Bethlehem Steel Company runs a ten-ton Girod furnace, melting cold charges, at Bethlehem.

Keller, in France, is making steel for the French Government with a modification of Girod's idea. He built a furnace in which he distributed electrodes in the hearth by taking a plate and putting it in the

bottom of the furnace under the refractory material, and attaching to it a number of half-inch rods which came up to the working surface where the metal lay. The refractory material was rammed around these rods. He had two to three hundred half-inch rods forming a regular grid coming through the bottom of the furnace to which electrical attachment was made, ramming in between them broken carbon in order to make the mass more conductive. If he rammed in carbon alone it would be dissolved out by the steel and the bottom would keep coming up, so he used a mixture of carbon and magnesite, which proved very satisfactory, covering it up with a surfacing of magnesite. He built a large number of furnaces which have operated very satisfactorily with this grid of electrodes embedded in the bottom.

Someone then thought: "Is not the material of the hearth conductive enough, when hot, to carry the current?" The first furnace of that type that I saw was in operation in Sheffield, England. The method followed was to take a grid electrode and embed it in the hearth, leaving the prongs embedded but not quite reaching through the hearth to the metal above it. When cold, this refractory layer was an insulator, but when hot a good enough conductor; and so a direct electric connection between the bottom electrode of the furnace through the hearth material to the metal bath was formed.

The hearth material itself becomes impregnated with oxide of iron during use, and thus becomes better conducting, so much so that the furnace can be started up cold. Electrical connection is thus formed through the material which forms the basic hearth itself.

A number of furnaces have been designed on this principle, with the electrode embedded in the bottom of the hearth. They are sometimes built with the hearth electrode of graphite and iron, or of iron with graphite terminals, embedded in the hearth material, with the hearth material packed and rammed in on top of it. These furnaces are further developments of Siemens' idea of taking the current off from the bottom of the containing vessel.

The Heroult arc furnace uses two electrodes—one to put current into the charge and the other to carry it away. The idea is to have two arcs in series, to have current passing from one electrode through the slag to the metal, through the metal, and thence back to the other electrode. With very cheap power, labor, and scrap material available, Heroult was in a position to make very large profits, and founded a successful steel business. Heroult did more perhaps than anyone else to make electrical steel commercial.

Heroult also devised and obtained French patents for a combined furnace, which was intended for use as a Bessemer converter and electric furnace. His electric furnace was similar in shape to the open-hearth furnace, except that it was heated by electrodes passing through the roof. He interested the U. S. Steel Corporation in his patents and sold them for a large sum. The U. S. Steel Corporation has actively made use of them itself, and has also built furnaces for other people. The furnaces are splendidly designed, as well as being on a good working principle. The type having two electrodes and two arcs has been largely replaced by those having three electrodes and three arcs, for the latter three-phase type is the cheaper and more adaptable form of furnace. There are about two hundred and fifty of these furnaces in use in the United States.

There is another type of furnace which does not use the arc—the resistance furnace, where the metal is heated by the resistance of a solid or liquid material. There are a number of such furnaces. The first was devised by Gin, who used simply a ractangular hearth provided with a long serpentine groove connected with two heavy terminals, and capable of carrying a very heavy current. The object was to melt down the metal by its own resistance, and to keep it at the proper temperature. Nothing but the resistance of the metal itself, lying in the groove, was relied upon to melt it and keep it at the correct temperature while being refined.

The resistance-radiation furnace is one where the metal is heated by radiation from the resistor, the latter being heated by the direct passage of the current. That is the principle of the Bailey furnace which is used for heating bars and ingots and for melting metals such as brass, but not yet for melting steel. The channel filled with broken carbon is just beneath the roof of the furnace, which collects the heat generated as it is reflected against it, and radiates it back onto the charge on the hearth.

There is another type of this resistance furnace where the material to be melted is put in crucibles and the conducting material by which it is to be heated (the resistor) is packed around the crucibles. This type of furnace does not, however, find much popularity, for it has defects and shortcomings which prevent it from becoming a commercial success, though it is very satisfactory as a laboratory furnace.

There is a type of resistance furnace which depends upon the pinch effect. Liquid metal in small channels communicating with a larger bath of metal, is heated by its own resistance. This is the basic principle of the Hering furnace. The electrodes carrying current to these channels are water-cooled. This type of furnace has received many modifications, among which is the use of current generated in the tubes by induction, so doing away with electrodes (Ajax-Weil-Hering furnace.) This introduces complications, but yet it has merit by doing away with electrodes, and is now in successful operation.

The induction furnace is also a resistance furnace; it was originated by Mr. Colby, of Newark. He thought it possible to melt metal by means of induced

currents. He experimented at the General Electric Company laboratories and took out patents, but never brought it to a commercial outcome. Ferranti conceived the same idea in England at about the same time. The first to use this idea commercially was Kjellin in Sweden, about 1902. He used bars of steel which had been made in other furnaces, merely melting them down in this furnace which he used as a melting crucible. He built a small furnace of 500-pound capacity, then one of 1000-pound, and made steel in large quantities.

The Germans (Roechling and Rodenhauser) took up the idea and increased the size of the furnace by multiplying it—making a combination furnace of two circles. Even a three-circle furnace run by three-phase current, has been devised.

It is a great feat to construct these complicated furnaces and to get them to work—to melt steel and yet to keep the coils cool enough so that their insulation is not destroyed. The principal drawback with this type of furnace is its lack of exposed metal surface, so that it is difficult to refine material in them. They are also very expensive, and an accident to them is a very serious matter.

There is a type of induction furnace which has recently been brought out by Dr. Northrup, with rapid oscillating current, which does not need a magnetic circuit, and so is simpler in design. It has many advantages over the ordinary type of induction furnace, but has also some complications not found in them. It has reached the laboratory stage and is developing hopefully toward the commercial field.

Electric Furnaces for Non-Ferrous Metals

The metals particularly in mind are brass and bronze, copper and aluminum being secondary in consideration. Brass contains zinc, a metal fairly volatile at a bright red heat. The considerable loss of zinc by volatilization must be guarded against. If brass is made in an electric furnace of the proper construction, volatilization and oxidation of zinc may be reduced to a very small amount (1 to 3 per cent).

The radiation furnace, which radiates heat directly on the metal, is very inefficient for this sort of work, boiling out the volatile materials very rapidly from the part of the surface which becomes over-heated. This disadvantage of the arc-radiation furnace has been overcome by active circulation—rocking of the furnace or circulation of the bath, thus keeping the metal at a uniform temperature. This principle is being utilized very efficiently in brass furnaces, which work by arc radiation and yet lose very little zinc by volatilization.

Having now in very summary fashion outlined the electric furnace art, particularly its development in the direction of melting metals, such as steel and brass, I will leave the field to the special writers who will tell of the particular construction and operation of their several types of electric melting furnaces.

THE GREAVES-ETCHELLS FURNACE

BY F. W. BROOKE

Electric Furnace Construction Co., Philadelphia.

The Greaves-Etchells system suses the delta-Y connection, which is admittedly the best combination for producing evenly loaded phases. The transformers are connected delta on the primary side and Y on the secondary. One of the legs of the transformer is applied directly to the bottom of the furnace by means of copper busbars and a copper plate, which conducts the current through a bottom composed principally of magnesite and dolomite, in such a way that there is a graded resistance, beginning with a low resistance and ending high. The other two legs of the transformer are connected to movable electrodes, which extend down through the roof. Regulation is then maintained by the usual types of furnace regulators. It is readily seen that by this arrangement there is no possibility of either movable electrode ever touching the bath or extending into it, without causing a short circuit. This feature alone is very valuable, and one which is very hard to handle in a large number of other types of furnaces.

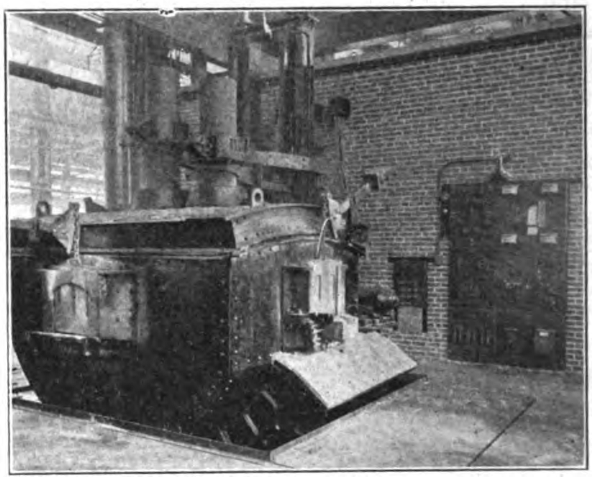


Fig. 1—Greaves-Etchells Three-Ton Electric Furnace, Showing Control Board

By a careful analysis of the conditions described above, it will be noted that the combination of a resistive bottom and the delta-Y connection of transformers is one which prevents serious overloading of one phase, at the same time doing away with a specially high reactance, which is necessary on other makes of furnaces.

Metallurgically, a furnace which uses the bottom as a resistor, and therefore as a heat producer, is superior

to one which generates all the heat above the bath. This is especially true of the production of alloy steel, where materials are used which have a higher specific gravity and also higher melting point than the steel itself. Rabbling becomes unnecessary in the Greaves-

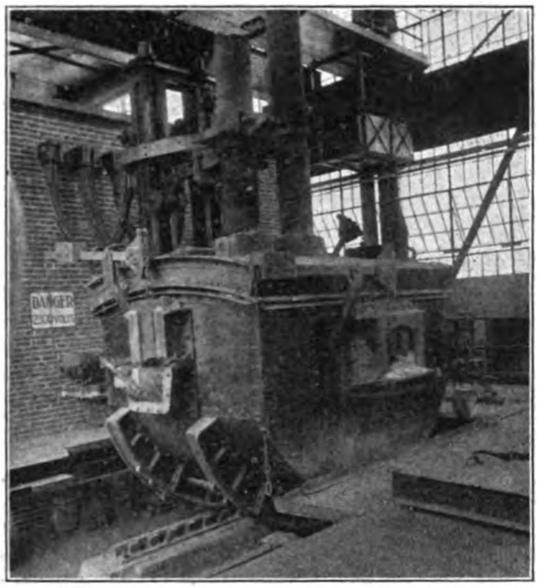


Fig. 2—Greaves-Etchells Three-Ton Electric Furnace, in New Foundry, Navy Yard, Philadelphia, Showing Rocking Device

Etchells furnace, and the roofs last longer, since they are not punished so severely. Two voltages are used, the high voltage for melting down and the lower for refining.

A study of the shapes of the lining of the electric furnaces of the arc type now in commercial use, brings out many practical points which tend to give power economy and added life to the refractory side walls of the furnace. The first and most important point

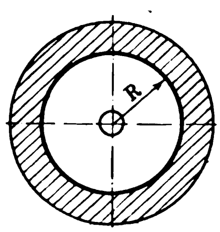
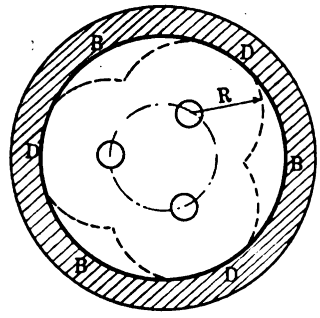


Fig. 3

Within heavy line represents metallic bath. Sectioned areas represent refractory sidewalls.

to bear in mind is that heat generated in the electric arc will be dissipated radially in the horizontal plane from the center line of the electrode, from which we see, on referring to the illustrations herewith that Fig. 3 would give the most ideal shape. In this shape, the cold metal would be uniformly melted, that is, that with uniform scrap charged evenly into the furnace every piece of scrap lying on the outer edge of the lining would melt at the same time, and in practical language, there would be no "cold spots" or "hot spots."

This shape was used in the early single-phase furnaces, but had the very obvious disadvantage of being only applicable to single-phase furnaces, which today are no longer being considered by either the prospective buyer or the power companies who supply the power.



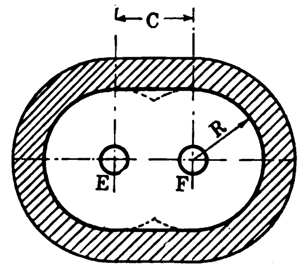
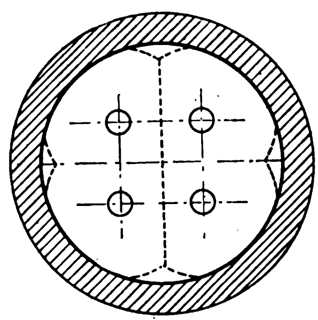


Fig. 4 Fig. 5

Within heavy line represents metallic bath. Sectioned areas represent refractory sidewalls.

Applying these views to circular furnaces, so generally adopted by the "three-top-electrode" furnaces, as shown in Fig. 4, it will readily be noted that when the cold scrap has become melted at the points A, there will be decided areas or masses of unmelted scrap at the points B, and were it practically possible, such a furnace would require a three-leaf shamrock shape to give ideal conditions. This, however, is not practical, and in order to melt the whole of the



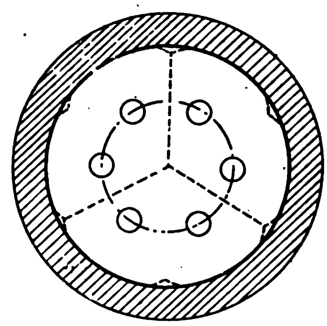


Fig. 6 Fig. 7

Within heavy line represents metallic bath. Sectioned areas represent refractory sidewalls.

charge in furnaces of this design, it becomes necessary to superheat certain parts of the charge, which means extra expenditure of power, and develops three very decided hot spots at points A, with its corresponding damage to the lining.

The designers of the three-phase furnaces (three-phase current being now in general use) which have two (or multiples of two) electrodes carried through the roof (the third phase of each bank being connected directly to the conductive hearth)are in a better position to avoid these wasteful hot and cold spots, particularly in the two-electrode and six-electrode type

of furnaces, and proportionately so in the four-electrode type.

Referring to Fig. 5, where the oval type of lining is used, it will be noted at first sight that there would be a tendency for two small cold spots to develop, but in actual practise this is not the case, as the heat dissipated from, say, electrode E is carried away radially and uniformly through the charge and a certain percentage through the lining, except in the direction of the electrode F. In this direction the heat is dissipated through the charge but is then "heat insulated" by the heat being dissipated by this electrode F. By arriving at a certain balance of the distance C, the ideal conditions of Fig. 3 can be obtained with a three-phase load.

Referring back to conditions enumerated in Fig. 4, it will be readily seen that as the number of electrodes for a circular furnace are increased, the conditions of hot and cold spots are gradually reduced as shown in Figs. 6 and 7. Shapes shown in Figs. 5, 6 and 7 are used in the Greaves-Etchells design.

MOORE RAPID "LECTROMELT" FURNACE

BY R. D. THOMAS
Pittsburgh Electric Furnace Corporation

In considering the steps in the advancement of a new process of manufacture the fundamental reason for the introduction of the new process is sometimes lost sight of. A discussion of the electric furnace for the manufacture of high-grade steel immediately raises the question as to why the older steel making processes are now being replaced.

Some years ago all high-grade steel was made by the crucible process. In this process pure steel scrap is charged into a pot holding about 100 pounds and melted. The resultant steel has the analysis of the mixture charged, no impurities being removed. This process has all the disadvantages of small quantity production plus very expensive raw material. In more recent years the open-hearth method has been perfected to a point where comparatively high-grade steel is produced. In this process the steel is melted on an open hearth by the heat of burning fuel impinging on the surface of the bath. The refining of the steel, that is the reduction of phosphorous and, to a minor extent, the removal of sulphur, is done in this process, but the refining processes are constantly handicapped by the avidity with which the molten steel picks up from the fuel the very impurities which the metallurgical reactions are removing, and the inability to maintain a reducing atmosphere and very high temperature necessary for the effective removal of the sulphur.

The heat being applied as fuel burned above the bath, places severe punishment on the roof refractories. This, in turn, necessitates the rather slow application of the heat to prevent burning down the furnace. As a consequence the average open-hearth heat is in the furnace from 8 to 15 hours, depending on the kind of steel being produced. As a corollary it will be noted that the output of a 30-ton open-hearth furnace will be in the neighborhood of 50 tons per day.

The electric steel furnace of the rapid type comes into competition with these two older steel-making processes and shows many advantages, some of which may be listed briefly:

1. Neutral heat which has no effect on the metallurgical reactions of the steel-making process. The atmosphere in the furnace chamber may be made oxidizing or reducing at the will of the operator.

2. The application of the heat directly to the bath permits of a much more rapid application of heat than in the open hearth without the destruction of the refractories.

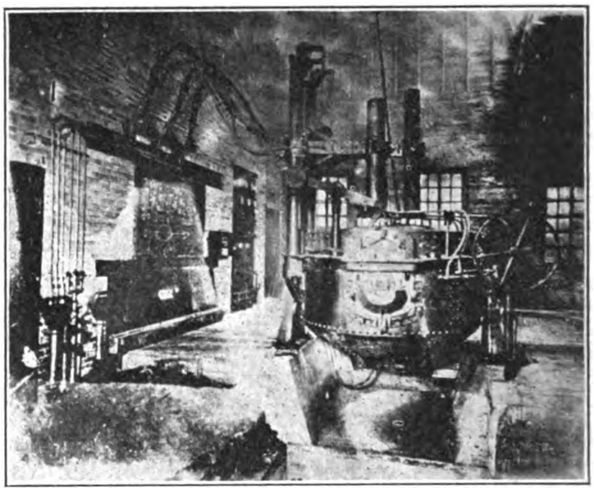


Fig. 1—One and One-Half Ton Moore Electric Steel Furnace

3. The reduced time to make a heat reduces the furnace capacity required for a given daily output. Some makers of electric steel furnaces take especial advantage of this feature and there are three-ton electric furnaces in operation which makes as much steel in a day as, or more than, a 30-ton open hearth.

4. Better quality steel can be produced in the electric furnace than in the open hearth. Electric steel is equal to the highest grade of crucible steel and, due to the fact that the heats are larger, it is more uniform in quality.

5. Electric steel can be pre-heated to temperatures higher than can be obtained in the open hearth or crucible, and the greater fluidity obtained makes for decidedly better steel castings, especially where the casting is of thin cross-section.

The best type of electric furnace for steel making is generally conceded to be the one with the arc struck between the electrodes and the bath. Three electrodes are usually employed. While this general type is followed by most of the present manufacturers of elec-

tric furnaces there are very wide variations in the design of the various furnaces which make for the wide differences in operation. These differences do not generally affect the quality of the steel produced. A good operator can make high-grade steel in the crudest "home-made" furnace, but the electric furnace to be commercial must conform to certain standards of economy of investment and operation. It must likewise be as near foolproof as possible, easy of repair, rapid and reliable in operation.

The furnace shown in Fig. 1 has certain features worthy of special note. The inverted dome-shaped bottom of the furnace prevents any possibility of floating the furnace bottom through the expansion of the shell, as the bottom refractories are arched in place. A practical feature of considerable importance is the absence of all mechanism from the furnace pit. The tilting mechanism, instead of being placed under the furnace, is placed above the floor and the tilting motor is mounted on a bracket to the side of the furnace where it is easily accessible and out of harm's way from molten steel slag and dirt. The electrode winch motors are placed in the transformer room and are away from all the dirt, heat, water and dust which is always present where they are mounted on a furnace. (Fig. 2).

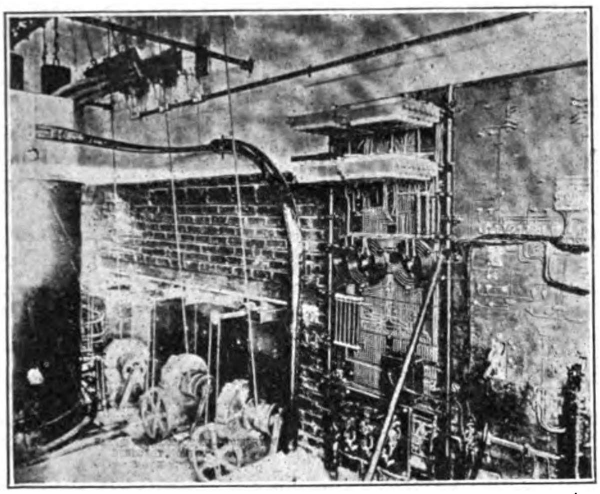


Fig. 2—Rear of Power Board Showing Location of Electrode Winch Motors

The conducting arms of this furnace are also the electrode supporting arms, a fact which permits placing the insulation between the furnace shell and the arms back at the supporting columns where it is not subject to the rapid deterioration from the heat above the furnace. This composite electromechanical electrode arm avoids the cumbersome duplicate electrical arm with mechanical arm to carry the electrodes heretofore used.

The distinctive feature of this furnace is its rapidity of operation which also spells efficiency and output. During the melt-down period there are no metallurgical reactions which require appreciable time, so that any reduction in the melt-down time correspondingly reduces all heat losses. The usual time of melt-down in this furnace is one-half hour to three-quarters of an hour, and a heat of casting steel heat may be produced from cold metal in one hour or less. This rapid melt-down feature is not obtained merely through the use of comparatively higher capacity transformers, but the whole design of the furnace is such that it will take care of the rapid power input. That the design is successful in this respect is proved by roof lives of more than 200 heats and power consumption on individual heats as low as 380 kw-hr. per ton. Another advantage of the rapidity of action is the greater output per ton of furnace capacity. This means that a smaller furnace, with an attendant lower investment, is required for a given daily output. Generally speaking the capacity of this high-powered furnace is approximately one-half that of the average-powered electric steel furnace for the same daily output.

The question of power factor is one that is of constant interest to the power companies. Some electric steel furnaces run as low as 50 per cent with the majority having a power factor between 80 per cent and 90 per cent. There is no design reason why the power factor cannot be made above 95 per cent, but there is a very practical consideration which will make a power company reluctant to connect up a furnace with too high a power factor. During the first portion of the melt-down there is a period—short or long depending on the speed of operation of the furnace—when momentary short circuits occur. The value to which the current will rise on these momentary short circuits varies greatly with the power factor. The lower the power factor the less will be the line disturbance. Power plants not having a large reserve may find it desirable to have their furnace load at power factors in the neighborhood of 70 per cent to prevent undue fluctuations in the load. However, as previously stated, the majority of furnace installations are best designed for average central-station conditions for a power factor of 80 per cent to 90 per cent.

WEEKS ELECTRIC FURNACE

BY S. H. OURBACKER
American Metallurgical Corporation, Philadelphia.

Industrial heating is divided into three classes—namely

Low Temperature, ranging up to 750 deg. fahr.

Medium Temperature, ranging from 750 deg. fahr. to 1700 deg. fahr.

High Temperature, ranging from 1700 deg. fahr. up.

The lower range of heat is applied to drying, japanning, vulcanizing, core baking, general heating of liquids and melting of low-melting-point alloys.

The medium range of heat is applied to melting of non-ferrous metals, heat treating, vitreous enameling, annealing, carbonizing and case hardening.

The higher range of heat is applied to the melting of metals of high melting point such as steel, brass, ferro-alloys, etc.

In the lower range electric heat is produced by the use of resistance ribbons running at black heat or at a slight glow. In japanning where explosive gases are produced, the oven is ventilated by an exhaust fan. In core baking or other baking or drying applications, the ventilation is regulated according to the explosive or objectionable nature of the gases emanating from the work.

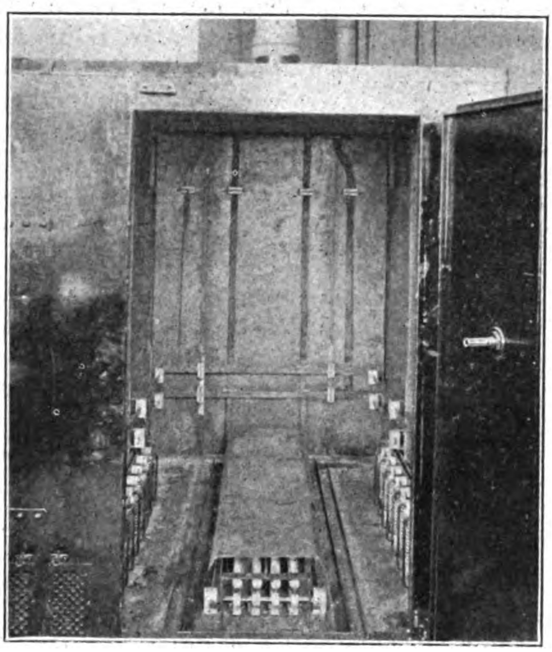


FIG. 1—INTERIOR VIEW OF ONE COMPARTMENT OF THREE-COMPARTMENT TUBE BAKING OVEN, SPRAGUE ELECTRIC WORKS, Bloomfield, N. J.

Each compartment 3 ft. 6 in. wide, 6ft. deep, 6 ft. high, 17 kw. connected.

In the medium range of heat, resistance ribbons are used running at high temperatures and radiating the heat to the work. No ventilation is used in this type and the furnaces are carefully bricked and heat-insulated to give as low a radiation as possible.

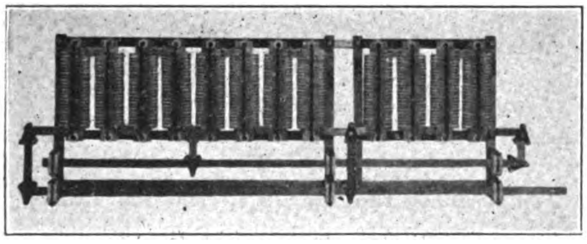


FIG. 2—METHOD OF MOUNTING AND CONNECTING WALL-MOUNTED HEATERS

In the higher temperature, heat is usually produced by electric arcs either of the open or smothered type, or either coke or carbon resistance.

Electric heating today is of extreme importance to all central stations from the standpoint of a desirable load. It is possible through electric heating loads to obtain a large power consumption. As an example, in one large manufacturing concern in this country there are 13,000 kw. of industrial electric heating installed. An average figure which is possible amongst small users of industrial electric heating, not including melting furnaces, would be in the neighborhood of 85 kw. per customer.

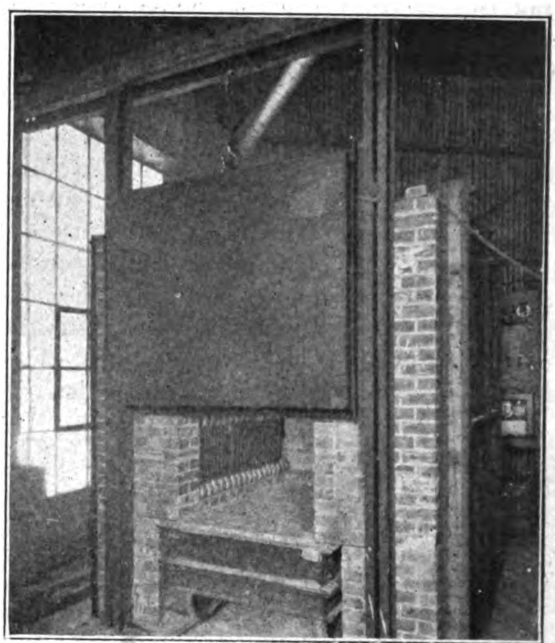


FIG. 3—ELECTRIC HEAT-TREATING FURNACE, CONNECTICUT ELECTRIC STEEL CO., HARTFORD, CONN.

52 in. deep, 36 in. wide, 32½ in. high, 40 kw., maximum temperature 900 deg. cent.

The advantages of electric heat are numerous. Some of it is produced at a high thermal efficiency as the power put into a furnace is transformed directly into heat and produced at exactly the points desired.

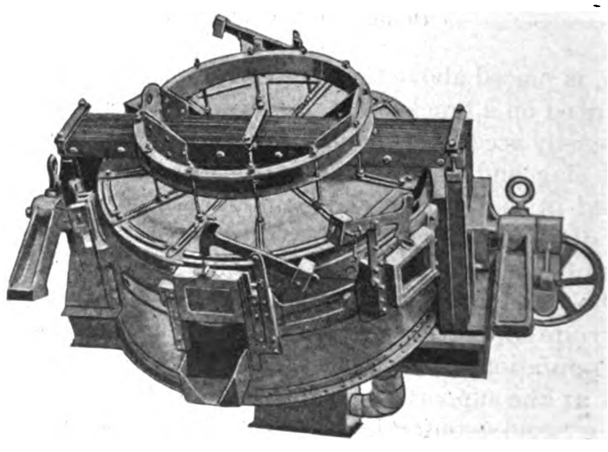


FIG. 4—500-LB. INDUCTION FURNACE

Absence of flues, objectionable gases and excessive heat radiated from the furnace, cleanliness, neatness of appearance and the advantages of temperature control, without the necessity of a skilled operator, are some of the chief advantages.

Fig. 1 shows the class of oven applied to the low-

temperature work. This type of oven is especially adapted for japanning and core baking, and drying work. The temperature is maintained constant by automatic heat-controlling instruments. With such an instrument it is unnecessary for the operator to make any adjustments after the proper temperature is set on the instrument, thus reducing the labor cost, as practically unskilled operators can be used.

Fig. 2 shows an illustration of the type of unit usually employed in low-temperature work. The heating element here is a non-corrosive resistance metal capable of long life.

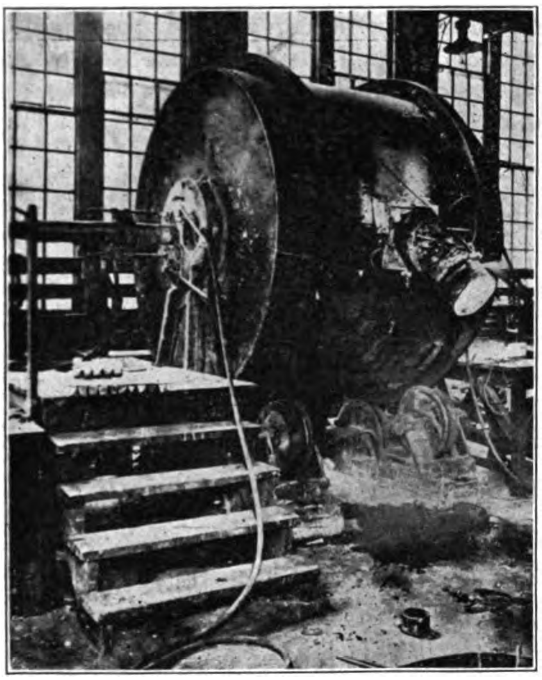


Fig. 5—Weeks Electric Rotating Furnace

Fig. 3 shows the type of furnace employed in the application of medium range heat. It will be noted that the furnace is of standard type of mill construction and that the heat units are placed on the side walls in place of burners as in oil-fired furnaces.

The heating ribbon is installed by placing in the lining of the furnace specially moulded refractory insulating blocks and hanging the ribbons upon them.

In the higher temperature work a number of different types of furnaces are employed. In the production of steel there is the arc and induction type, and as for brass there are a smothered arc, open arc and coke resistor types. Fig. 4 shows the latest development in this country on the induction furnace for the melting of steel. The writer wishes to point out the importance of this recent design as it appears to solve the difficulties which have been encountered in induction furnaces up to the present time. It is well-known that the induction furnace is the most desirable type of furnace to produce high-grade steels due to lack of contamination difficulties contributed to electrodes.

The great objection to the induction furnace has been the rapid circulation of the metal, which was caused by opposing electrical forces between the primary coil and the bath which is the secondary circuit. This circulation at such high temperatures will break down any refractory known, thus causing considerable lining trouble. This has been overcome in this design by placing a pancake coil directly above the bath so that the opposing forces have no tendency to rotate the metal. In order to insure proper mixing, the furnace is placed on trunnions and can be tilted slightly, thus varying the cross-section of the bath and causing any degree of rotation desired.

Fig. 5 shows the Weeks rotating brass furnace. This picture is an illustration of the first installation in this country, which was made at the works of the General Electric Company some eight years ago, and produced two tons of brass per heat. In this type of furnace the metal is melted by the open single-phase arc produced by horizontal electrodes passing through the center axis of the drum. It is necessary in using an electric arc for melting brass to keep the metal thoroughly mixed in order to prevent the zinc content from boiling out, since zinc volatilizes at a lower temperature than the melting point of copper. This has been accomplished by rotating the drum about the electrodes which constantly mixes the superheated surface with the colder metal at the bottom of the bath, thus keeping the bath at a uniform temperature and the zinc so well mixed with the copper that volatilization is a minimum.

A few words as to the power characteristics of the different types would be interesting.

All of the types of furnaces using the resistor ribbon can be operated either single-phase or polyphase and at practically unity power factor. The load installed on these types of furnaces varies from a few kw. up to around 500 kw. at the present time. However, this is not a maximum as any size installation is entirely practical from an engineering standpoint.

Induction furnaces run either single or polyphase. The type shown under this present development (Fig. 4) is a single-phase furnace having a capacity of 500 pounds per melt with 150 kv-a. installed. The power factor is between 60 and 70 per cent. These furnaces, although of lower power factor, give approximately the same load as a continuous resistance load.

The Weeks furnace operates single-phase and has for the 1/2-ton size a kw. rating of 200 and for the one-ton size 300 kw. The power factor averages around 80 per cent.

To the central stations, industrial electric heating is an extremely satisfactory load and consumes large amounts of power per customer. The load is practically continuous during the day time and in the majority of cases for twenty-four hours.

AJAX-WYATT ELECTRIC FURNACE

BY G. H. CLAMER
The Ajax Metal Co., Philadelphia.

The Ajax-Wyatt electric furnace is an induction furnace of the vertical ring type. An induction furnace is in reality merely a transformer with a single-turn secondary.

From the earliest days of the alternating-current transformer, it has been known that if such transformer were badly designed, namely, with insufficient core iron, or insufficient carrying capacity of the conductors, that losses would occur, due to the conversion of electrical energy into thermal energy.

Mr. Edwin A. Colby, of Newark, and Deferranti of England, each conceived the idea about the same time of so magnifying the heating effects in a transformer that an actual melting equipment resulted. To do this it was necessary to have a current path of sufficient resistance in proportion to the current flowing through it that actual melting, and superheating would take place. They accordingly constructed a transformer, on one leg of which was placed a primary coil, and a body of refractory material surrounded the opposite leg, in which was formed the channel, or groove, for containing liquid metal in the form of a single turn. In such a construction there was great magnetic leakage, hence, a low power factor.

Kjellin, a few years later, made a furnace of better transformer construction by placing his primary coil concentrically within the secondary coil, (the liquid metal bath). With this construction, having provided means for protecting the primary coil from the heat of the liquid metal, a much better power factor resulted. With this design of furnace, the power factor becomes relatively lower as the capacity of the furnace (size of ring) becomes greater. The Kjellin furnace was the first furnace of the induction type to meet with commercial success. Many patents and improvements have since been issued, such patents covering means for bettering the power factor, details of construction, and for two- or three-phase operation.

In Europe, the induction furnace is today largely in commercial use for steel melting, but in this country in such use it has met with very indifferent success due mainly to refractory troubles. Schneider, President of the Great Creusot Steel Works of France, and the Past President of the British Iron & Steel Institute, first conceived the idea of constructing a furnace with a closed channel of constant dimensions, and hence constant resistance, and having a bath above such column of liquid metal, thus providing a hydraulic head. He constructed a furnace in accordance with this idea, but after spending a considerable amount of money on it, was forced to abandon it because of the destruction of the refractory material surrounding the secondary loop.

In the Schneider furnace one end of the secondary loop was joined to the main bath at a higher level than the other end, the idea being to promote circulation due to the natural tendency of heated bodies to rise because of the difference in density. By incorrect proportioning of the secondary loop of metal slow circulation, due to thermal effect alone, would result. Because of slow circulation and the rapid conversion of electrical energy into thermal energy in the secondary loop, known as the resistor, the refractory materials would soon be brought to a temperature at which they fuse.

The next step in the development of the furnace I am about to describe, was the invention of Dr. Carl Hering. Dr. Hering found that it was possible to so proportion a liquid metal resistor, that when the current flowing through it was of high density, a force of considerable magnitude exerted itself upon the

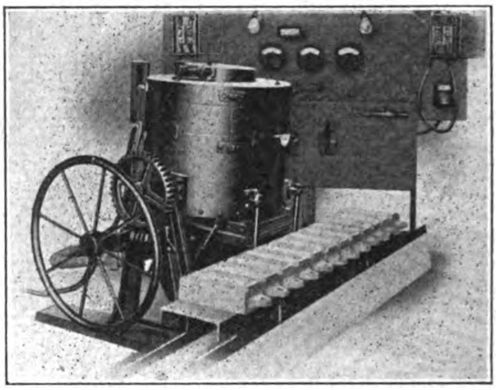


FIG. 1—AJAX-WYATT FURNACE

central section of such a column of liquid metal. By reason of this force, which he termed "pinch pressure," a rapid circulation would ensue, causing the liquid metal to be ejected from the center of the column and the cooler metal to flow into it at the periphery. By reason of the "pinch pressure" being exerted, the circulation becomes so rapid that overheating of the resistor walls does not result to nearly the same degree.

It is well-known that conductors in close proximity, and carrying current in the same direction, attract each other, whereas those carrying currents in the opposite direction repel each other.

Taking advantage of this phenomenon, Mr. James R. Wyatt added the further improvement of using this force, known as "motor effect," to circulate still more energetically the liquid metal in the resistor. By the very simple means of so constructing the resistor that it forms an acute angle, thereby causing the current to flow in opposite directions in the two legs of the triangle so formed, "motor effect" of considerable magnitude is set up at the angle. As the conductor (the liquid metal) is held in stationary walls the conductor cannot be bodily repelled, but the conductor being liquid is free to move and the metal is forced out of the resistor channel at the far sides, and

the cooler metal flows in to take its place on the inner sides of these channels.

The Wyatt furnace is a furnace in which the resistor is preferably placed in a vertical position and the main bath above the resistor. In the resistor rapid circulation ensues because of the combined forces exerted therein, namely, "motor effect," "pinch effect," and "thermal effect." Each of these forces tends to force the metal upward. The strongest force exerted is that due to "motor effect" which is applied in greatest degree of force at the angle, which is so placed that it is at the extreme bottom of the furnace.

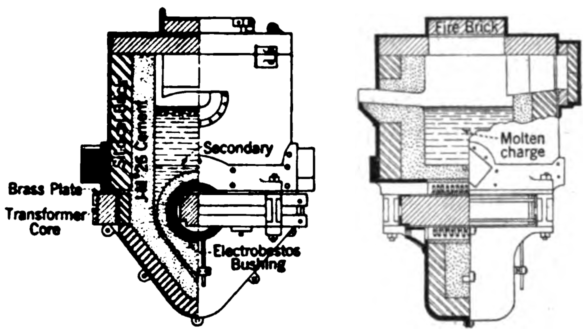


Fig. 2—Sectional Views of the Furnace

In such a furnace the heating and the stirring is all applied from the bottom (the logical place). No mechanical contrivance is necessary to produce circulation, or mixing. The conversion of electrical energy into thermal energy is 100 per cent, such transfer being accomplished in metal being heated. The heat losses are merely those due to radiation, and the small transformer losses.

The Ajax-Wyatt furnace has thus far been developed only for melting the copper-zinc alloys. It is possible to handle the full commercial range of such alloys as is used in rolling mill practise. Development work is progressing in adapting the furnace to other uses, and it is expected that it will shortly be possible to handle all the non-ferrous alloys in this furnace, and possibly some of the ferrous metals.

The characteristics of the Ajax-Wyatt furnace are the following:

1. Absolutely steady load.
2. Power factor—from 75 to 85 per cent, depending upon the size.
3. The metal is always the hottest part of the furnace.
4. No difficulty in getting required temperature for pouring.
5. Temperature under absolute control.
6. Thorough mixing without mechanical devices.
7. Due to shape of the hearth, or crucible, there is presented the smallest amount of exposed surface.
8. Lining cost per pound of metal melted, exceedingly small.
9. Requires minimum of attention.
10. The product of this furnace, because of the great uniformity and freedom from oxidation, is pronounced superior to that resulting from crucible, fuel-fired melting.
11. Efficiency on 60-kw. furnace, 11¼ pounds melted per kilowatt-hour. With 100 per cent efficiency the melting rate would be 12½ pounds per kilowatt-hour. Melting efficiency therefore 90 per cent. This seems almost unbelievable, but it is the day in and day out melting rate of the furnace covering period during which millions of pounds have been melted.
12. Metal losses—absolute minimum.

The drawbacks of this furnace are:

1. Lack of flexibility, by which is meant that it must be started with a liquid charge, and a portion of the charge must always be held in the furnace. This makes it difficult to change from one mixture to another, notwithstanding the fact that the electrical regulation provided is sufficient to take care of any of the copper alloys.
2. The furnace should always be kept heated by keeping a sufficient amount of current on the furnace to supply the heat losses.

Nine kw. is a little more than sufficient for this purpose on a 60-kw. furnace.

For intermittent operation, the leads may be plugged to low-voltage taps and the furnace sealed up after placing a layer of charcoal on the metal, and thereafter it requires no attention and is immediately ready for maximum melting efficiency when recharged

INTER-LABORATORY INSTRUMENT COMPARISONS

During the past month the Bureau of Standards has cooperated in a comparison of the standards of the various laboratories of one of the largest electrical manufacturing concerns in the country. This company has laboratories in a number of cities of the United States and a set of instruments for measuring electrical current, voltage, and power was carried from one to another of these laboratories, and to the Bureau of Standards. The instruments were carefully checked against the working standards of each laboratory. The results show a very gratifying agreement between the various plants and indicate that the standards in use by the electrical industry at large, so far as they are affected by this manufacturer, are satisfactorily uniform. The tests have also been of value in showing that the different types of instruments tested maintain their accuracy under various conditions of transportation.

Relative Advantages of Modern Steam and Electric Locomotives*

THE subject of the electrification of railroads was debated at a joint meeting of the New York sections of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, on October 22nd, in the Engineering Societies Building, New York. The interest taken in this subject was indicated by the size of the audience which filled all of the seats and all of the standing room in the auditorium. Mr. E. B. Katte presided in conjunction with Mr. H. W. Buck and Mr. W. S. Finlay, Jr.

F. J. SPRAGUE

President, Sprague Safety Control & Signal Corporation

Mr. Sprague, the first speaker, said that he wished to record his unchanging belief in the coming supremacy of electric power for transportation, and that his faith was based,—not upon a vast disparity between the best which can be built in a steam or electrical locomotive, nor upon any overwhelming claims of superior fuel economy when both are dependent upon coal supply, nor upon any material saving in operating expense sufficient to pay the charges incident to the increased capital cost when considered on existing traffic density and methods of operation,—but rather upon the broad ground of the overwhelmingly vital demand for *increased capacity*, a demand which ultimately can be met only by the electric system, because of characteristics individual to it.

Of course, there are inherent differences between the steam locomotive and its rival. The former is a moving power plant, limited both as to its maximum and its continuous rate of power development by the capacity of its boiler and portable fuel supply. It has, it may be granted, a certain apparent advantage because of its independent entity, but that very independence limits its capacity,—not materially in maximum traction effort,—for any locomotive can slip its wheels,— but in the amount of energy, that is, the product of speed and draw-bar pull, which is possible.

The electric locomotive, on the other hand, is but the user and transformer of electric energy created at distant power stations and transmitted to it by stationary conductors, and, thanks to the multiple-unit system any desired concentration or distribution of power units, under a common control, can be had, and any number of power plants, taking their energy from the centuries-old and diminishing supplies, or the annually renewed frozen white coal of the mountains, may be joined together in common supply.

And in that most difficult field of railroading, typified by the passage across the Great Divide, another and individual characteristic appears,—the power to make every train descending a grade act as a moving power plant to aid the others which are climbing it, as well as to provide a most effective braking mechanism.

But why the need of this great concentration of power, this possibility of increased unit-energy which is a function of speed? It is the demand,—insistent, threatening and vital—of increased capacity. Our modern life is dependent in a large measure upon two things, communication and transportation. The steam advocate will tell you that with regard to rail transportation its needs will be met by added trackage and augmentation of the power of his equipment. For the time being it will be, but how about the future?

There will come a time when duplication of tracks and increases in bridges, tunnels and terminals, and the power of individual units will reach practical limits, when physical facts will rebel against engineering dictum or operative demands, and then the way, and the only way, to meet the demand for increased capacity is by increase of speed, which can only be obtained when unlimited power is at the command of the operator.

Already the electrification of railway terminals is an essential; suburban service has long been in operation, and through operation of freight and passenger trains on mountain and other main line roads satisfactorily negotiated. The same kind of service which characterizes suburban operation can be as readily applied to the longer local runs, such as those between New York and Philadelphia.

As the demands increase, it will become more and more necessary to eliminate as far as possible non-essential rail transportation, and among such will be that coal which can be better burned at or near its source of supply and have its energy transmitted by wire.

Of course, the general electrification of trunk-line rialroads is not a matter of immediate possibility of accomplishment. It will only come as it is coming, progressively with the accelerating power of example. It will be governed very largely by financial conditions.

J. E. MULFIELD

Railway & Industrial Engineers, Inc.

Mr. Mulfield, the next speaker, said that, when we discuss or recommend the further electrification of the whole or any part of the 260,000 miles of steam-operated railroad system in the United States, which is now making use of about 65,000 steam and 375 electric locomotives for its passenger, freight and ter-

**Extracts from addresses delivered at the N. Y. Section meeting, October 22, 1920.*

minal service, the most important item involved is a correct and complete statement of facts, comparing the most up-to-date steam with similar electric operations, after which immediately come the important factors of the necessary financing and legislation.

While there is much existing steam road trackage that can and should receive first consideration as regards electrification for the purpose of eliminating gases from underground terminals and tunnels and to give relief to terminal or line traffic congestion in the vicinity of large commercial and industrial centers, it would be financial suicide to electrify immediately adjacent connecting and intermediate mileage, particularly in view of the improvements that can be made in both existing and new steam locomotives in the matter of reducing smoke, sparks, cinders and noise and in increasing general efficiency and economy in operation and maintenance.

With the decreased value of gold and purchasing power of the dollar has come an increase of from 4 and 5, to 7 and 8 per cent in the cost of money, which, in combination with the 100 to 150 per cent increase in the cost for labor and material makes the procurement today of the most pressing railroad capital needs almost prohibitive. Therefore, when engineers and politicians propose reckless superpower plans for the electrifying even of such belts of steam roads as lie in the densely populated district between Washington, D. C., and Boston, at a new capital cost approximating a billion of dollars, and in addition mark off the books the principal value of existing steam locomotives, passenger cars, shops, and terminal and intermediate facilities that would be unsuitable for the electrified service, they are planning either a new road to railroad bankruptcy, or a further burden in traveling and shipping costs, or in taxes, which would be representative of criminal waste instead of increased earning capacity by means of more efficient and economical operation.

Therefore, before the electric locomotive can be made permissible for general application the electrical engineer must reduce his first costs; promote interchangeability; provide a motor which will efficiently, economically and flexibly cover a wide range of speeds and not break down or deteriorate from overloading and heating; reduce complication, wear and corrosion in transmission and contact line apparatus; and substantially reduce the current losses between the point of power production and the locomotive draw-bar. Likewise the steam railway mechanical engineers, locomotive builders and specialty manufacturers, if they are to guard the steam locomotive and continue it in its present field of usefulness, must become more active in modernization and bring about improvement that will substantially increase its capacity and thermal efficiency by the use of higher steam pressures and superheat; compounding; more efficient methods of combustion; utilization of waste exhaust steam and products of combustion heat; better distribution and use of live steam; reduction of dynamic weights; greater percentage of adhesive to total weight and a lower factor of adhesion; and by a substantial reduction in standby.

The immediate requirements of new money for the more urgent steam equipment and facilities needed to provide adequate, safe and expeditious rather than luxurious service in the regeneration of the railroads, is the obvious reason for the continued utilization of the over-all more economical steam operation, and only after the possibilities in this direction have been realized can any serious financial consideration be given to the proposed radical change to super-electrification.

F. H. SHEPARD

Director of Heavy Traction, Westinghouse Electric & Mfg. Co.

Mr. Shepard stated that the demand for traffic movement will undoubtedly be doubled in about 12 years; so the question arises as to how we are going to handle it. The limit to physical expansion of railroad line and of terminals has been just about reached in many cases, on account of both the prohibitive cost and the inefficiency of terminals of unworkable size. A large measure of relief can still be secured by line and terminal revisions and improvements, but when the inevitable increase in the demand for traffic movement of the future is considered, these improvements savor, more or less, of expedients to secure relief which can only be temporary and very limited in degree.

The yearly average of 22 miles per day for a freight car for the whole country, with monthly averages of as low as five miles on some of our most congested railroads for a single month, emphasizes the fact that this is a problem that some how, some way, we must solve. The solution lies, to a large extent, in railroad electrification.

With the present standards of train make-up, classification and terminal handling, electrification will double the capacity of any railroad. With the better equipment we can expect in the future, together with the evolution of improved methods of operation contingent on electric power, this capacity should be doubled again, thus securing four times the present capacity. This should certainly be accepted as a vision of the future, and why not our aim? Unless some broad and consistent program is embraced, the situation, which is serious indeed today, may well be calamitous tomorrow.

The electric locomotive has generally, thus far, been a mere substitute for the steam locomotive, although, in some cases, due to the greater power of the electric locomotives, there has been a modification of the handling of traffic.

The advantage of electric power is its great flexibility and mobility. The difference between locomotives, steam and electric, is fundamental. The steam

locomotive carries its own power plant, while the electric locomotive, on the other hand, is simply a transformer of power. The design of the steam locomotive is circumscribed utterly by the necessity of tying up the rest of the machine to the steam boiler. On the other hand, the electric locomotive assembly can differ amazingly as to type, length, axle loading and driving connections. A group of small motors does not differ materially from a single large motor in efficiency. The speed and power, therefore, of an electric locomotive is limited only by conditions of track and construction and condition of car equipment. It thus becomes entirely practicable to build an electric locomotive to take any train which will hold together, over any profile whatever, and at any desired speed. Therefore, it should easily be practical to very greatly increase the speed of our freight trains so that they could all run at a common speed not very different from that at which the superior trains are operated.

A. H. ARMSTRONG

Chairman Electrification Committee, General Electric Co.

Mr. Armstrong presented a number of tables showing comparative figures for steam and electrical operation, covering relative economy of fuel, hauling capacity, maintenance charges and general flexibility.

A comparison of the modern steam and electric locomotive leads immediately to a discussion of the relative fitness of the two types of motive power to meet service conditions. At present, railway practise has closely followed steam engine development, but are we not justified in looking at the transportation problem from the broader standpoint of a more powerful and adaptable type of motive power?

Place at the disposal of an experienced train dispatcher a locomotive capable of hauling any train weight that modern or improved draft gear can stand, at any speed permitted by track alignment regardless of ruling grade or climatic conditions, that can be run continuously for a thousand miles with no attention but that of the several operating crews, and witness what he can accomplish in his all important task of expediting freight movement. It is not merely a question of replacing a Mikado or Mallet by an electric locomotive of equal capacity. The economies thus effected are in many instances not sufficient in themselves to justify a material increase in capital account. The paramount need of our railways today is improved service and this can be brought about by introducing the more powerful, flexible and efficient electric locomotive. Marked changes in present railway practise will undoubtedly follow the adoption of a type of motive power that is free from many of the limitations of the steam engine.

From the comparative performance data given, the author summarized the principal advantages of electric traction as follows:

1. No structural limits restricting tractive effort and speed of electric locomotive than can be handled by one operator.

2. Practical elimination of ruling grades by reason of the enormously powerful electric locomotives available.

3. Reduction of down-grade dangers by using regenerative electric braking.

4. Very large reduction in cost of locomotive maintenance.

5. Very large saving of fuel, estimated as two thirds the total now burned on steam engines in operation.

6. Conservation of our natural resources by utilizing water power where available.

7. Material reduction in engine and train crew expense by reason of higher speeds and greater hauling capacity.

8. Increased valuation of terminal real estate following electrification.

9. Increased reliability of operation.

10. Material reduction in operating expense due to elimination of steam engine tenders and most of the company coal movement, the two together expressed in ton-miles approximating nearly 20 per cent of present gross revenue ton mileage.

11. Large reduction in effect of climatic conditions upon train operation.

12. Postponement of immediate necessity for constructing additional tracks on congested divisions.

13. Attractive return on cost of electrification by reason of direct and indirect operating savings effected.

14. Far-reaching improvements in operation that may revolutionize present methods of steam railroading.

H. B. GATELY

Chief Engineer, Locomotive Superheater Co.

Mr. Gately claimed that the data submitted by the advocates of electric traction have been far from satisfying to the men who are obliged to decide the question of steam or electricity for traction. There has been great lack of publicity with respect to the total investment, and the return on the investment, in electric operation of trains.

It is futile to discuss fuel per drawbar horse power, or maintenance cost per hundred engine miles, without some idea of what the return on the capital investment will be. The engineering public, as a rule, has no conception of what it has cost the railway company for the various electrified divisions about which so much has been said. It is hoped that some data on this point will be forth-coming tonight.

Mr. Muhlfeld has concisely pointed out the economic problem confronting the railroads. To electrify existing steam-operated roads is at present more nearly impossible in a financial sense than ever before. Reference to the financial pages of newspapers and magazines in the last six months will confirm the statement that the soundest and best railway organizations have had to pay 7 per cent, and upwards, for money needed to maintain their properties. Roads in a less secure financial position are unable to obtain funds, even at these high rates. Unless it can be conclusively

proved that the return on the investment, all factors being considered, is better than with steam operation, the electrification of our main lines, and the extension of present terminal electrifications may, as has been said, be the electrical spelling of catastrophe.

It may be well to consider the unusual position in which the railroad systems of the country now find themselves. Embarrassed and restricted by years of repressive legislation, which often prevented the carrying out of constructive programs planned to safeguard future operation, then forced to undergo the trying and critical experience of government control, they are now facing a reconstruction period which must make up for a three year's hiatus in maintenance and replacements. This must be done almost at once.

It is further to be noted that in a great many of the public utterances and published articles, dealing with main line electrification, and in which reference to, and comparison with, the steam locomotive has been made, the conditions of comparison equitable then are not fairly representative for the present day. These comparisons have too frequently been made between almost obsolete saturated steam locomotives, on the one hand, and the new and thoroughly up-to-date electric locomotives on the other. It is only fair to insist that comparison be made with the modern superheated steam locomotive.

F. J. COLE

Chie Consulting Engineer, American Locomotive Co.

Mr. Cole stated that in all the papers and reports of the electrical installations, we find much about the advantages and much of what has been accomplished, but we search in vain for a complete financial statement showing at what cost in dollars and cents all this is accomplished. Many electrical installations are necessary for special needs such as are mentioned elsewhere, but it has yet to be proved that there is any great demand for the wholesale electrification of railroads in this country.

From the rusty rails and grass-grown tracks of many ill-considered electrical suburban lines running through sparsely settled districts, which do not earn sufficient rates on the investment to warrant a decent upkeep, we can obtain some appreciation of what would result from electrification of railroads if pushed beyond its natural limitations at the present time.

From the standpoint of cost, the question of steam versus electric operation in one which all the factors which make up the respective costs of different installations have to be considered. Thus, in the case of electricity, the entire cost of changing over from steam operation must be taken into account. This includes many items, the cost of which is difficult to obtain and is not usually published, such as, power houses, overhead or third rail construction, change in methods of signaling, shops, tools and appliances necessary for the maintenance of electrical equipment. For electrification it is customary to supply power station capacity in boilers, engines, turbines and generating apparatus largely in excess of the normal demand, located in more than one station so that there may be no interruptions in the supply of current. Two power stations were supplied in the case of the New York Central Terminal, each of which I believe was sufficient to supply power, if necessary, to the entire electric zone. This is, no doubt, very desirable and proper, but it must be included when the cost of electrification is considered. Presumably railroads are now in possession of the necessary appliances for steam operation, and electrification means that much of such equipment must be diverted into other channels, or discarded, so that in figuring the total operating and capital charges for electrification it is necessary to keep these items well in mind.

The electrification of terminals, tunnels and certain mountain divisions where water power is available, are now recognized as desirable installations. Among such are the Grand Central Terminal and the Pennsylvania entrance in New York City, the Baltimore & Ohio tunnel through Baltimore, the Hoosac Tunnel, the Cascade Division of the C., M. & S. P., and perhaps the Norfolk & Western, Elkhorn Grade. Some of these are absolutely necessary, regardless of cost.

Then, too, there may be a few zones in this country which by reason of density of traffic and coordination with the electrified terminals could probably be changed from steam to electric power with profit and quicker dispatch of business.

The reports of electrifications do not give costs of installation, how much was spent in changing over from steam to electricity, or what interest is paid for the money so expended, so that costs of future electrification *can* be accurately forecast. *This* is the question which should be answered—Is it cheaper to operate by steam or by electricity, and can freight per ton mile be moved at less cost (when all expenditures are considered) by electricity than by steam?

The details should not be featured to the exclusion of the whole installation. There are, admittedly, many attractive characteristics of electric power, but when it comes to a *wholesale* replacement of steam locomotives, especially on roads not peculiarly adapted to electrification, those responsible for the financial returns to the owners and to the public, may well hesitate and ask to be shown the cost, not only of the installation under consideration, but of those now in operation, and the probable return on the investment for the large expenditure they are asked to approve.

DISCUSSION

The discussions were by C. H. Quin, Chief Electrical Engineer, Norfolk & Western Railroad; A. W. Gibbs, Chief Mechanical Engineer, Pennsylvania Railroad System; W. L. Bean, Assistant Mechanical Superintendent, New York, New Haven & Hartford Railroad; F. H. Hardin, Chief Engineer of Motive Power, New

York Central Railroad; R. Beeuwkes, Electrical Engineer, Chicago, Milwaukee & St. Paul Railroad, and W. F. Kiesel, Jr., Mechanical Engineer, Pennsylvania Railroad.

The closure to the discussion was by Mr. George Gibbs, Consulting Engineer, Pennsylvania Railroad, who said in part:

I cannot go into technical details tonight, but I think our electrical friends will concede, and mechanical men must, in light of sufficient evidence furnished by existing installations, that an electric system will function in a successful, reliable and efficient manner for any kind of railway service. It is capable of unlimited hauling capacity, is flexible as to speed and has important features conducing to safety in handling trains. It is however, to the fundamental question affecting its adoption which I wish to draw attention; "Is the substitution of electric for steam haulage warranted by its advantages in the production of more transportation, and if so, is it practicable financially?" No sweeping generalization to the effect that electric traction will be used because it functions well will impress railway managers; they must have the answer to the above question.

Now, as regards the first portion of this query, it would appear that there are a number of important situations in which electric traction will produce results which cannot be had by the steam locomotive, notably in increasing existing track capacity, especially on lines having heavy grades, in hard shifting, in suburban and terminal services, and in location (such as in tunnels) where the absence of combustion is necessary or desirable. Such installations should be undertaken if financially feasible, and this can only be determined by a critical examination of each case. Assuming that the money can be raised for an improvement which will pay, it will be found that electric traction will pay, directly or indirectly, in the special cases to an extent depending upon the density of traffic and the difficulty of maintaining proper steam operation. It must be admitted that an electric installation involves a higher first cost than for steam, in fact, its adoption means that more or less existing investment must be scrapped, therefore, the increased in fixed charges must be offset either by the direct operating savings produced or these plus the indirect savings and benefits. The latter may mean avoidance of permanent way additions, a permissible change in operating methods, more traffic moved, and new kinds of traffic produced. The direct savings have been under discussion tonight; in spite of some difference in opinion, I think we cannot escape the conclusion that there is always a large saving in fuel with electric traction, generally some saving in maintenance cost of "power equipment" and often important savings in train crew costs, engine house expenses, minor supplies, etc.

Sometimes these "direct" savings will be sufficient to return a handsome profit over and above charges; if not, the indirect savings must be included. It will avoid future disappointment if we face the facts; the electrification of the railways of the country as a whole, or the electrification of the whole of any extensive component system, is neither practicable nor desirable, measured by costs and results; the doom of the steam locomotive has not been sounded and will not be in our time. But the fact that electrification is not universally applicable should not discourage anyone; it has a very large and profitable field (both for the railways and the manufacturers). These facts indicate the importance of carefully investigating each proposed application to insure that it is properly conceived and carried out.

ATHLETIC FIELD TO COMMEMORATE EMPLOYEE HEROES

The Western Electric Company is rushing the construction of a ten acre athletic field at its Hawthorne factory near Chicago to commemorate its 61 employees who sacrificed their lives during the war. It is believed that when completed this field will be one of the largest memorials in this country.

It is interesting in view of this memorial to note the report the Company has just circulated regarding the war activities of its personnel. 7,521 of its employees were actively engaged in some type of service during the period of hostilities. Of this number, 4,675 were in the army, and 1,253 entered the navy.

Because of their intimate familiarity with the various means of communication, the Western Electric employees had an exceptionally large representation in the Signal Corps; 609 members of its technical organization saw service with the telegraph battalions the field signal battalions and the telephone operator units. Infantry and artillery organizations also proved exceptionally popular drawing 1,721 and 824 men respectively.

The members of the big electrical concern were well represented among the commissioned and non-commissioned ranks of their respective branches of the service. The army personnel boasted 5 lieutenant-colonels, 8 majors, 28 captains, 68 first lieutenants, 116 second lieutenants and 683 non-commissioned officers. Of this aggregation 983 are known to have won promotion during the period they wore khaki; 2,299 of the company's men saw service over seas.

A present estimate of the casualties among those who entered the service shows that 52 soldiers were killed and 121 were wounded. The navy losses included 9 killed and 12 wounded.

Development on Radio Generators for the Army and Navy

BY F. I. HISS

Manager Small Motor Dept., Crocker-Wheeler Co., Ampere, N. J.

THIS article records an interesting war development of small machines of very special design carried out by the writer in 1917 for the Signal Corps and for the Bureau of Steam Navigation.

The company with which the writer is associated, as its share in war work was almost entirely engaged in the manufacture of motor generators, etc., for wireless service for the Government.

In the fall of 1917 the Crocker-Wheeler Co. was asked by the Signal Corps to develop a wind-driven generator, in cooperation with the Western Electric Co., which would be suitable to supply the energy to operate their radio telephone which was to be part of the standard equipment of the army airplanes.

In the PROCEEDINGS of March last year Messrs. Craft and Colpits describe the development of the whole telephone equipment; and in an article in the *Electric Journal* of May, 1919, Mr. H. M. Stoller, of the Western Electric Co., describes the operation of this generator and the method of control which he developed. He points out that the development of these machines proved to be a considerable problem in itself, as it was necessary to secure constant voltage over a range of speed from 4000 to 12,000 rev. per min., which corresponds to an airplane speed range of from 60 to 120 miles per hour. In addition to all of the ordinary requirements for power equipment there was the additional requirement of furnishing current free from commutator ripples and brush noise. The regulation was accomplished by means of special generator design and the use of an audion valve.

This generator is illustrated in these papers; and in the same issue of the *Electric Journal* is illustrated a similar design manufactured by another company, of which the Signal Corps asked assistance in view of very large production anticipated; but this generator, the writer believes, was still in the experimental stage when the armistice halted operations.

DESCRIPTION OF THE GENERATOR

The standard generator was to furnish approximately 70 watts at 25 volts and 50 watts at 275-300 volts for energizing the audion of the radio set, the use of batteries being almost out of the question due to the high voltage required and other obvious considerations.* The generator was driven by an air propeller and was mounted as found most convenient on the plane, generally strapped to one of the plane struts.

The machine was to be completely enclosed so that it could be exposed to the weather with impunity and was to offer as little air resistance as possible. Fig. 1 shows the machine with enclosing covers in place, and Fig. 2 another view with air propeller attached.

Fig. 3 shows the machine as finally developed with front and rear stream line covers removed and with the tube regulator and mounting, which parts were

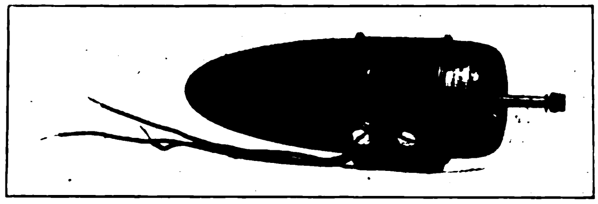


FIG. 1

supplied to the generator manufacturer by the manufacturers of the radio set. Aluminum parts were used wherever possible in order to cut down the weight to a minimum, and the stream line covers were aluminum spinnings $^1/_{16}$ in. thick.

The development of the first sample was completed early in 1918 and the machine put into commercial production shortly after, and at the signing of the armistice the production had been raised to about 200

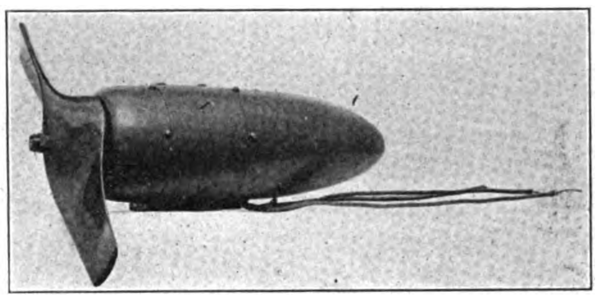


FIG. 2

machines per week, a total of between 2000 and 3000 machines having been delivered at that date some of which were put into service in France.

Fig. 4 shows a group of machines after test ready for shipment and after sealing by the U. S. Signal Corps inspector, at the plant at Ampere, N. J.

*It is interesting to compare the British practise during the war. In a paper by Major C. E. Prince in the *Journal of the Institution of Electrical Engineers* of May 1920, he mentions that originally they used dry batteries for the high-tension circuit and storage batteries for the low-tension. One of the first telephone sets without batteries weighed only 10 lb. while the high-tension batteries alone weighed 36 lb.

Later he mentions they adopted a wind-driven generator which supplied high and low-tension voltage with a storage battery floating across the low-tension side.

Again he mentions that there seems good reason to hope that in the near future a perfectly silenced and well balanced generator will permit the abolition of the battery, all current being supplied from the generator. He is apparently unaware of work which was accomplished in the development of this generator for the U. S. Signal Corps.

Development of the Generator

It was realized when the first sample was built that the main problem would be to build an armature which was sufficiently well balanced to operate smoothly at the maximum speed of 12,000 revolutions and which could be produced in large numbers on a commercial scale. With this end in view it was decided to attempt to build an armature which would

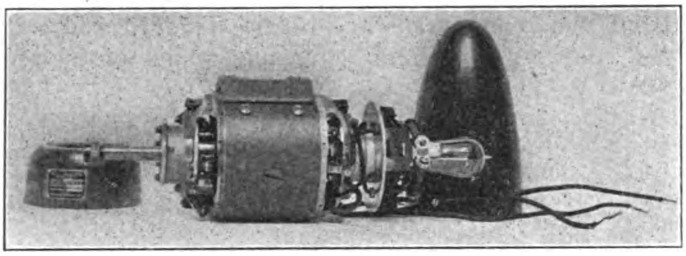


Fig. 3

be well balanced by virtue of design and accurate manufacture of its parts and not have to resort to static or dynamic balancing; and ultimately this end was completely obtained.

Though every machine delivered was tested and had to give steady voltage up to 12,000 rev. per min., not one of these armatures was given either a static or dynamic balance.

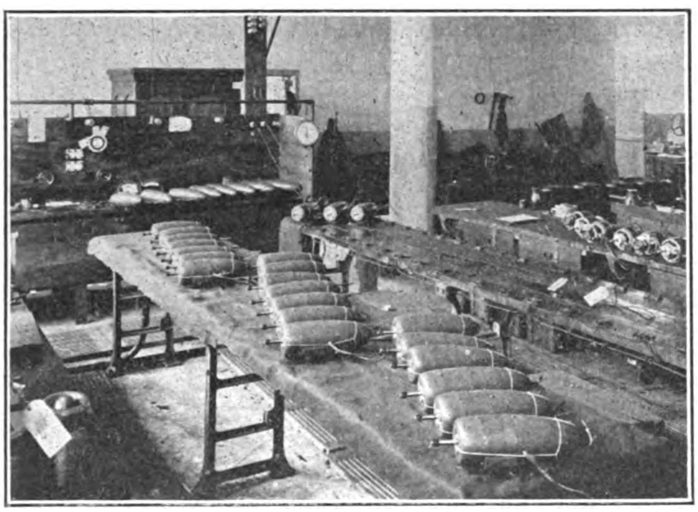


Fig. 4

Commutation was perfect up to 8000 rev. per min., and at this speed there was very slight vibration.

When the maximum operating speed of 12,000 rev. per min. was reached there was slight sparking but not an extent to cause injury either to brushes or commutator or excessive brush noise in the telephone. Further, each machine was given an overspeed test for one minute at 14,000 revolutions.

The remarkable running qualities of these armatures (see Fig. 5) were obtained in part by the following means:

1. Armature diameter was reduced to a minimum, that is 2 ½ in. over all.
2. A very large shaft was used having a ¾ in. diameter in the core.
3. Armature punchings were given the rather heavy press fit on the shaft of 0.004 in.

Ball bearings of the double-race type were adopted, but some trouble was experienced with the commercial bearing used, as it was found that the inner race of the bearing was not absolutely concentric, and vibration with resulting bad commutation was experienced due to the slight eccentricity of the inner race; but when this trouble was discovered and the manufacturers approached they went to endless trouble to correct it, with the result that the eccentricity of the inner race was held down to 0.0005 in. in all cases.

The commutators were designed and built with great care and only one case occurred of commutator destruction, this being due to a cracked steel flange,

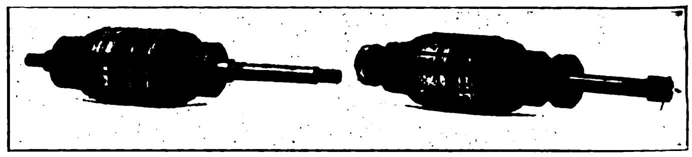


Fig. 5

one of the commutators bursting on the overspeed test.

The next problem was to provide a well balanced armature winding, and after very careful consideration it was decided to wind the high-tension winding of fine wire (No. 34 gage) by machine in the bottom of the slots, drawing each wire as tight as possible, and then to put a hand-wound low-tension winding over this to protect the fine wires of the high-tension winding.

After a good deal of practise this method of winding was worked out. The armature core was placed bodily in the cheeks of an armature winding machine and the high-tension winding put in, connected to the high-tension commutator, and the whole carefully insulated.

The low-tension winding was then wound in by hand. The result was that the high-tension winding was never disturbed or put under strain in any way during the process of winding, and the low-tension hand winding served to protect the high-tension winding like a tightly woven basket; and to this can be attributed the fact that the armatures showed no tendency after long periods of running to develop open circuits, due to breakage of the fine high-tension wire. In the early experimental type of this generator much trouble had been experienced, and was only eliminated when this method of winding was devised.

After the low-tension winding had been put in and connected the end windings were carefully protected

by a wrapping of seine twine. The armature was dipped and baked in Sterling varnish three times. Treatment with heavier compounds or impregnating the armature was tried, but was found unsuccessful as the absorption of large quantities of heavy compound in the winding tended to throw the armature out of balance.

Great attention was paid to the design of the brush gear of these generators. It was found that duplex

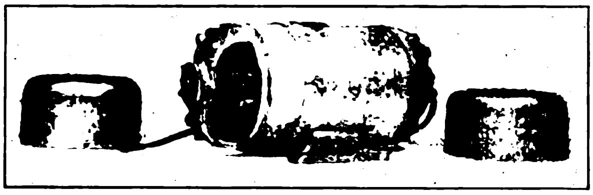


Fig. 6—Dynamotor Open

brushes under heavy radial spring pressure, the inertia of the brush being reduced to a minimum, gave as would be expected, the best results.

The very high brush pressure of approximately 15 lb. per square inch was used initially so as to guarantee a pressure of seven or eight lb. per square inch when the brush had worn.

On account of the intense vibration to which the machine was subjected every nut and screw used in any part was effectively locked, so that under no conditions could anything work loose.

1500-Volt Dynamotor

The devlopment of another interesting type of machine was undertaken and accomplished on very short notice for the Bureau of Steam Navigation for operating the wireless telegraph on Navy seaplanes.

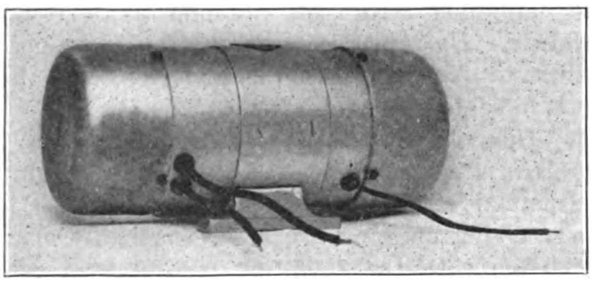


Fig. 7—Dynamotor Closed

Specifications called for a dynamotor with an output of 450 watts at 1500 volts, these dynamotors taking current from a 24-volt storage battery. A 1500-volt machine of this size was decidedly a novelty at the time and the department asked that 50 of these be designed and delivered in three months.

Some experimental work had been done in preparation for such a demand in the early days of the war and as the result of this experience the writer felt confident that a satisfactory operating machine could be built with one armature winding as against the obvious plan of winding two separate 750-volt armatures and putting them in series.

At the start it was realized that there would be no difficulty in maintaining insulation to ground for such voltage but that the difficulty would be to produce an armature winding which would not short-circuit between turns and which would not open-circuit due to the necessary use of very fine wire, subjected to extreme vibration.

Form-wound coils were discarded at the start as being unsuitable for such work due to the fact the wire would be put under strain when the coil was forced into the slots, and break connection with the commutator after a few hour's service.

On the other hand it was realized that if the winding were wound in by machine in the customary manner that large differences of potential would exist at all cross-over points at the ends of the winding and also would occur between adjacent sections of the winding in the slots.

The high-tension winding of these armatures was therefore completely sectionalized, that is, the turns between the adjacent commutator bars were completely insulated both at the ends and in the slots from each adjoining section. The maximum voltage existing between any part of this armature winding except where ample insulation was provided, did not exceed about 50

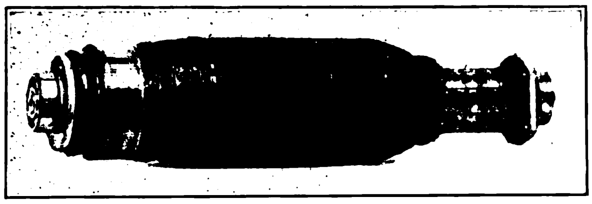


Fig. 8—Dynamotor Armature

volts, equal to the voltage between adjacent commutator bars.

It was also felt that no effort should be spared to get the best possible insulation on the wire itself, so the writer approached the Acme Wire Company with the suggestion that it might be able to manufacture a special insulated wire in No. 34 B. & S. gage, which was the size required for these armatures. In view of the importance of the work this concern immediately offered all its special resources, and as a result in about two or three weeks it was able to produce a wire following the author's suggestions which showed great improvement in dielectric strength of its covering.

A double-silk-covered enamel wire was run through the enameling machine, and in this way the silk was saturated and given an enamel coating, on the outside of the silk covering. Next this wire was run through the silk-covering machine, and an extra covering of silk put on, and finally this triple-silk-covered wire was again run through the enameling machine and an insulated wire produced, which was very superior to any commercial magnet wire obtainable and was found very suitable for the purpose of winding these high-voltage armatures.

After the high-tension winding had been wound in by machine, and completely insulated, the low-tension winding was wound over it by hand, protecting the high-tension winding very effectually against the effect of centrifugal forces.

Abstractive and Selective Properties of Radio Antenna Circuits

BY EDWARD BENNETT
Professor of Electrical Engineering, University of Wisconsin

(*Continued from page* 1004 *of JOURNAL for November, 1920*)

13. *The maximum power which an antenna can abstract from sustained waves and deliver to a detector.* To make the delivery of power from sustained waves to the detector associated with a *given* antenna a maximum, the equivalent resistance of the detector, R_d, should be made equal to the sum of the radiation resistance, R_r, plus the wasteful resistance R_w, of the antenna. Let us assume that the detector is so proportioned, and that the ratio of the resistance is as expressed in equations (**1**) and (**2**).

If an antenna has an extended capacity area at a height (h) and is resonant to the sustained impinging waves, the average power, P, delivered to the detector after the current attains the steady-state value, is

$$P = \frac{(E_{r.m.s.})^2}{4\,k\,R_r} = \frac{(h\,F_{r.m.s.})^2}{4\,k\,R_r} = \frac{(h\,F_m)^2}{8\,k\,R_r}$$

in which, F_m represents the peak value of the electric intensity of the impinging waves.

Substituting in the above equation, the expression for the radiation resistance of an extended flat top antenna, namely

$$R_r = \frac{4\,\pi\,h^2}{3\,s\,p_0\,\lambda^2}$$

the expression for the power becomes,

$$P = \frac{3\,s\,p_0\,\lambda^2\,F_m^2}{32\,\pi\,k} \qquad (17)$$

Since the dimensions of the flat top antenna do not appear in this equation, it follows that the power which can be delivered (after the oscillation has built up to the steady-state value) to a detector is independent of the height and area of the antenna network, *except in so far as the height and area may affect the value of k.* Throughout this discussion, it is assumed that the greatest dimension of the antenna is a small fractional part of the wave length.

It is of interest to put the above expression for the maximum power in a form fraught with greater physical significance.

$$P = \frac{3}{16\,\pi\,k}\,(s\,\lambda^2)\left(\frac{1}{2}\,p_0\,F_m^2\right) \qquad (18)$$

Now $\left(\frac{1}{2}\,p_0\,F_m^2\right)$ represents the energy in the dielectric per cubic cm. when the peak of the electromagnetic wave impinges upon the antenna, (s) represents the velocity of propagation, and (λ^2) represents the area of a square whose side is equal to the wave length,—*a wave length square.* Since the electric intensity F is a sine function of time, the average value of $\left(\frac{1}{2}\,p_0\,F^2\right)$ taken over the wave as it streams past the receiving station is 1/2 of $\left(\frac{1}{2}\,p_0\,F_m^2,\right)$ and since the electro-kinetic energy $\left(\frac{1}{2}\,\mu_0\,H^2\right)$ is equal to the electro-potential energy $\left(\frac{1}{2}\,p_0\,F^2\right)$, it follows that $(s\,\lambda^2)\left(\frac{1}{2}\,p_0\,F_m^2\right)$ represents the energy which streams past the receiving station per second across an area equal to the wave-length square. That is to say, the greatest average power which can be delivered to a detector by an antenna from impinging sustained waves equals $\left(\frac{3}{16\,\pi\,k}\right)$ times the power flowing across a *wave-length square* at the receiving station.

The above conclusion does not hold if the radiation resistance is partially neutralized by associating a power amplifier with the antenna as a *resistance neutralizer. By resistance neutralization* it is possible to abstract from the impinging waves more power than is indicated by equation (**18**).

14. *Directive Efficiency of a Radio System, and Abstractive Factor of an Antenna Circuit.* For the hypothetical case in which the wasteful resistances of a receiving antenna are made negligibly small in comparison with the radiation resistance, k reduces to unity, and the power which can be abstracted from impinging waves and delivered to a detector depends only upon the frequency at which the radio transmission system is operated, varying inversely as the square of the frequency. That is, for this hypothetical case, the amount of power which the antenna can deliver to the detector is inherent in the operating frequency of the *system* of radio transmission and in the distance between the sending and receiving stations. The suggestion is therefore made that the *directive efficiency of the system* be defined as the ratio of the power which would be delivered to the detector in this hypothetical case to the total power which would stream across the hemisphere on which

the receiving antenna is located if there were no refraction or absorption losses in transmission.

Since the power which would be delivered to the detector with no wasteful antenna resistance, is,—

$$P = \frac{3}{16\pi} s \lambda^2 \left(\frac{1}{2} p_0 F_m^2\right) \tag{19}$$

and since the power which would stream across the entire hemisphere (on the supposition of no transmission loss or refraction) is,

$$P_1 = \frac{4\pi r^2}{3} s \left(\frac{1}{2} p_0 F_m^2\right) \tag{20}$$

in which, r represents the distance between sending and receiving stations, it follows that the directive efficiency D_e of the system is,

$$D_e = \frac{9\lambda^2}{64\pi^2 r^2} \tag{21}$$

The directive effciency of a system of radio transmission varies directly as the square of the wave length, and inversely as the square of the distance between the stations.

In the actual antenna, in which the wasteful resistance is not zero but in which the sum of the wasteful plus the radiation resistance is (k) times the radiation resistance, the power delivered to the detector is $(1/k)$th of the hypothetical maximum expressed by equation (**19**). It is therefore suggested that $(1/k)$ be termed the *abstractive factor of the antenna circuit* A_f.

$$A_f = 1/k \tag{22}$$

At the higher frequencies (200,000 cycles and higher) an abstractive factor of 50 per cent at a time constant of 0.01 second can be obtained with an antenna of small volume and consequently of low cost. At the lower frequencies (60,000 cycles and lower) an abstractive factor of the order of ten per cent with a time constant of 0.01 second can be obtained only by building a costly antenna of enormous volume. The abstractive factor of many antennas (particularly coil antennas) is extremely low,—less than 0.001 of one per cent.

It should be noted that the abstractive factor, as defined above, can be made to exceed 100 per cent at the higher frequencies by resorting to *resistance neutralization.*

15. *The combination of frequency with antenna height and area which will lead to a high selective coefficient against "strays."* In the present state of the art, the interference with radio communication caused by "strays"—atmospheric or cosmic electromagnetic disturbances—is more serious than the interference resulting from other stations.

We proceed to consider the nature of these disturbances, to define what we mean by the selective coefficient of an antenna against disturbances of this type, and finally to determine the effect of the synchronous frequency and the dimensions of the antenna upon this selective coefficient.

There is no direct experimental evidence as to the wave form of the electromotive forces induced in the antenna by strays. The electromotive forces will, however, fall under one of the four forms shown in Fig. 8.

These four forms of stray electromotive forces are:

A. A continuous e. m. f. sustained for several natural oscillations of the antenna, as shown at (A) Fig. 8.

B. An impulse electromotive force, as shown at (B).

C. A rapidly damped oscillation of lower frequency than the antenna, as shown at (C).

D. A rapidly damped oscillation of higher frequency than the antenna, as shown at (D).

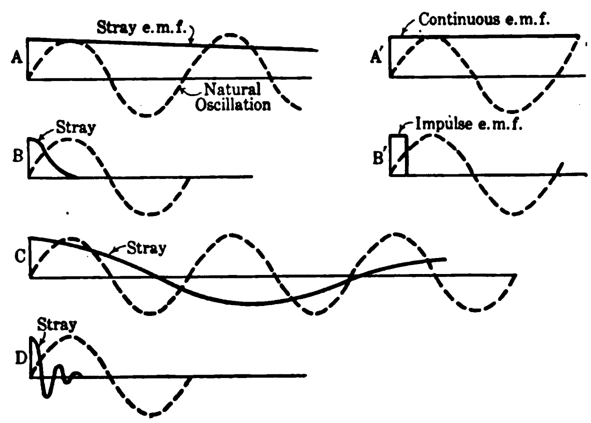


Fig. 8

In my estimation the heaviest lightning discharges are substantially dead beat discharges which induce in the antenna an electromotive force of the form shown at (A); or it is possible that they may be of the form (C) with a decrement greater than .5. In the case of those lightning discharges which are observed to be of great length (or of low frequency), while the radiation resistance alone would be sufficient to cause a decrement of the order of only .1, I would expect the wasteful resistance to greatly exceed the radiation resistance and to make the discharge deadbeat.

Some experimental evidence has been obtained in the study of lightning disturbances on transmission lines that small local discharges, which result in a redistribution of charge between neighboring portions of the atmosphere, may take place. Such discharges may be expected to induce in the antenna an impulse voltage of form (B).

The properties of an antenna to rapidly damped alternating e. m. fs. of the forms (C) and (D) may be inferred from the properties to sustained voltages of the form (A) and to impulse voltages of the form (B). For our purpose, then, there are interferent electromotive forces of only three types to be considered; namely:

(1) Sustained alternating e.m.fs. (already discussed).
(2) Sustained continuous e. m. fs. of form (A).
(3) Impulse e. m. fs. of the form (B).

We may feel assured that if those antenna proportions are determined which result in the highest selective coefficient to these three types, then these proportions will be the best for the intermediate forms. In order to make types 2 and 3 easy to treat, we assume that the wave form of the stray e. m. fs. is as shown at A' and B' in Fig. 8.

The term selective coefficient with a modifying prefix has already been defined for two sets of conditions. The *steady-state selective coefficient* of a receiving circuit against a specific detuned frequency has been defined as the ratio between the power delivered to the detector by sustained waves of a frequency such as to make the circuit resonant and the power delivered to the same detector by waves of the same intensity but of the specified detuned frequency: the power being determined after the current builds up to the steady-state value. The *selective coefficient for the time interval* T_e (the Morse dot interval) against a specified detuned frequency is defined as the ratio between the energy delivered to the detector by an impressed alternating electromotive force of a frequency such as to make the circuit resonant and the energy delivered to the same detector by an electromotive force of the same value but of the detuned frequency,—both electromotive forces being impressed for the same interval of time T_e.

The *selective coefficients for the time interval* T_e of a receiving circuit against a continuous electromotive force of the form A' (Fig. 8) or against an impulse electromotive force of the form B' will be defined as the ratios of the energy delivered to the detector by an impressed alternating electromotive force of a frequency such as to make the circuit resonant and the energy delivered to the same detector by the continuous electromotive force or by the impulse electromotive force, respectively; the peak or maximum values of all three electromotive forces are to be the same, and the alternating electromotive forces is to be impressed for the time interval T_e. (The impulse electromotive force will, of course, be impressed for the impulse interval only). The interval T_e will be the Morse dot interval with some methods of receiving, and the beat interval with others.

TABLE VI

RELATIONS BETWEEN THE DIMENSIONS OF AN ANTENNA AND THE ENERGY EXPENDED IN THE DETECTOR BY AN IMPRESSED CONTINUOUS ELECTROMOTIVE FORCE.

NOTE: $R_d = R_w + R_r = k\,R_r$

1	Form of antenna	Parallel plate	Elevated disk	Vertical wire	Square loop
2	Induced voltage peak (E)	$h\,F$	$h\,F$	$h/2\,F$	$\frac{2\pi N h^2 F}{\lambda}$
3	Capacity, approximately (C)	$\frac{p_0\,a}{h}$	$8\,p_0\sqrt{a/\pi}$	$\frac{2\pi p_0 h}{\log h/r}$	$\frac{p_0\,\lambda^2}{16\pi^2 N^2 h}$
4	Stored energy ($1/2\,C\,E^2$)	$1/2\,p_0\,a\,h\,F^2$	$4\,p_0\sqrt{a/\pi}\,h^2\,F^2$	$\frac{\pi p_0 h^3 F^2}{4\log h/r}$	$\frac{p_0 h^3 F^2}{8}$
5	Initial current peak ($2\pi f\,C\,E$)	$2\pi f\,p_0\,a\,F$	$16\sqrt{\pi a}\,f\,p_0\,h\,F$	$\frac{2\pi^2 f p_0 h^2 F}{\log h/r}$	$\frac{h\,F}{480\pi N}$
6	Radiation resistance (R_r)	$\frac{4\pi f^2 h^2}{3 s^3 p_0}$	$\frac{4\pi f^2 h^2}{3 s^3 p_0}$	$\frac{\pi f^2 h^2}{3 s^3 p_0}$	$\frac{64000}{243\pi s p_0}\left(\frac{h f}{s}\right)^4 N^2$
7	Initial power expenditure in detector	$\frac{8\pi^3 s p_0 k a^2 h^2 F^2}{3\lambda^4}$	$\frac{512\pi^2 s p_0 k a h^4 F^2}{3\lambda^4}$	$\frac{2\pi^5 s p_0 k h^6 F^2}{3\lambda^4(\log h/r)^2}$	$\frac{2000\,s\,p_0\,k\,h^6\,F^2}{243\pi\lambda^4}$
8	Relations between dimensions, frequency, and time constant	$a\,h = \frac{3 s^3}{16 k\pi^3 T_c f^4}$	$a^{\frac{1}{2}} h^2 = \frac{3 s^3}{128 k \pi^{5/2} T_c f^4}$	$h^3/\log h/r = \frac{3 s^3}{8\pi^4 k T_c f^4}$	$h^3 = \frac{243\pi s^3}{16000\,k\,T_c\,f^4}$
9	Stored energy, in terms of frequency and time constant	$\frac{3 p_0 s^3 F^2}{32 k\pi^3 T_c f^4}$	<———	<———	$\frac{3 p_0 s^3 F^2}{16 k\pi^3 T_c f^4}$
10	Energy from resonant freq. to detector in interval T_e	$\frac{3 b T_e F^2 s^3 p_0}{32\pi k f^2}$	<———	<———	$\frac{30 b T_e F^2 s^3 p_0}{163\pi k f^2}$
11	Selective coefficient for interval T_e	$2\pi^2 b\,T_e\,T_c f^2$	<———	<———	<———
12	Initial power expenditure in detector in terms of freq. and time constant	$\frac{3 p_0 s^3 F^2}{32 k\pi^3 T_c^2 f^4}$	<———	<———	$\frac{40 p_0 s^3 F^2}{163 k\pi^3 T_c^2 f^4}$
13	Selective coefficient against first cycle	$\pi^2 b\,T_c^2 f^2$	<———	<———	<———

16. *The effect of the antenna dimensions upon the energy expended in the detector by a sustained continuous electromotive force.* The relation between the antenna dimensions and the energy expended in the detector by a sustained continuous electromotive force may be rapidly determined by making use of the well known relation that when a continuous electromotive force is suddenly impressed in a circuit containing a condenser, the energy expended is equal to the energy eventually stored in the condenser.

Antennas divide into the four forms listed in Table V.

TABLE V

FORMS OF ANTENNAS

Parrallel Plate Antennas: Antennas having a capacity area of such great extent as compared with the mounting height

that the capacity of the antenna is inversely proportional to the height, the capacity being given approximately by, $C = \frac{p_o\, a}{h}$

Disk Antennas: Antennas having the extended capacity area mounted so high that the capacity is approximately independent of the height—being approximately equal to

$$8\, p_o \sqrt{\frac{a}{\pi}}$$

Vertical Wire Antennas: A single vertical wire, the capacity of which is approximately proportional to the height; the capacity being expressed approximately by the relation

$$C = \frac{2\,\pi\, p_o\, h}{\log h/r}$$

Coil or Loop Antennas: If the dimensions of the coil are so small in comparison with the wave length that the distributed capacity may be neglected, the inductance of a single turn square loop antenna having a side length (h) which is 1000 times as great as the radius of the wire is expressed approximately by the relation

$$L = 4\,\mu_o\, h$$

Table VI shows the relations between the dimensions of antennas of these four forms and the energy expended in the detectors associated with the antennas. In arriving at these relations, it has been assumed that in each case the greatest dimension of the antenna is small in comparison with the wave length corresponding to the resonant frequency of the loaded antenna.

Referring to Table VI. Line 2 gives the induced electromotive force in terms of the electric intensity F. F represents the sustained e. m. f. induced per centimeter of height of the flat top antenna by the impinging disturbance. (It is to be noted that throughout this paper, the calculations are based upon the hypothetical case of a wave front perpendicular to the surface of the earth). For the vertical wire antenna, the net value of the induced voltage is $F\,h/2$.

Line 4 shows the energy which will be stored in the condensors whose capacities are given in Line 3 under impressed electromotive forces of the values shown in Line 2. An equal amount of energy is dissipated in the resistances during the charging process, and of this dissipated energy one-half is expended in the detector. From this line it will be seen that the energy delivered to the detector by a sustained continuous "stray" electromotive force increases directly as the ($a\,h$) product (or as the volume under the antenna) in the case of the parallel plate condenser, and almost as the cube of height in the case of the vertical wire and loop antennas.

From Line 7 it will be seen, however, that the *initial rate* at which energy is delivered to the detector (or the power expenditure in the detector during the first oscillation caused by the stray) increases directly as the *square* of the volume under the parallel plate antenna, and almost as the *sixth power* of the height of the vertical wire and loop antennas. The initial power expenditure in the detector equals $1/2\,(I_p)^2\,k\,R_r$, in which I_p represents the initial peak value of the charging current. The values of the initial current peak as given by the relation

$$I_p = 2\,\pi\, f\, C\, E$$

are written in Line 5.

In order to obtain a small amount of energy from the stray, the antenna dimensions must be small. But in the attempt to reduce the interference from strays, the dimensions of the antenna should not be reduced below the point at which the time constant of the antenna has increased to .01 second. The relations between the antenna dimensions and the time constant have been written in Line 8. On substituting the expression for the dimensions from Line 8 in the expressions for the stored energy as given in Line 4, the expressions for the stored energy which appear in Line 9 are obtained. From this line it is seen that the energy obtained from the continuous e. m. f. varies inversely with the length of the time constant, and inversely as the fourth power of the resonant frequency. On the other hand, the energy obtained in the time interval T_e from impinging waves of resonant frequency varies inversely as the square of the frequency. The expressions for the energy delivered to the detector in the time interval T_e by an alternating e. m. f. of resonant frequency, having a peak value equal to the value of the continuous e. m. f., are written in Line 10, in which the value of the factor b depends only upon the length of the time interval T_e as compared with the length of the time constant T_c. If T_e is a Morse dot interval, .05 second, and T_c = .01 second, b equals 0.8. The values of b may be read from Curve E of Fig. 6.

The selective coefficient of each antenna for the time interval T_e will be found by dividing the expressions for the energy from the resonant e. m. f. appearing in Line 10 by the expressions for one half the energy from the continuous e. m. f. which appear in Line 9. The result of this division is written in Line 11. The selective coefficient for the interval T_e against a sustained continuous stray electromotive force is seen to vary directly with the length of the time constant of the circuit and directly with the square of the resonant frequency.

$$S_c \text{ (against a continuous e. m. f.)} = 2\,\pi^2\, b\, T_e\, T_c\, f_r^2 \qquad (23)$$

Line 12 contains expressions for the initial rate at which energy is expended by the continuous e. m. f. in the detector. The rate is written in terms of the resonant frequency and the time constant of the circuit. These expressions have been obtained as the result of the elimination of the antenna dimensions from the Line 7 expressions for the initial power by means of the relations given in Line 8.

Line 13 is the result of dividing the expressions for the energy from the resonant frequency which appear in Line 10 by the time interval T_e and then by the

expressions from Line 12 for the initial power expenditure. Line 13 represents the ratio of the average rate at which energy is delivered to the detector by the resonant electromotive force to the initial rate at which the continuous electromotive force delivers energy to the detector. These ratios may be designated as the *selective coefficient against the first cycle.*

$$S_c \text{ (against first cycle)} = \pi^2\, b\, T_c^2 f_r^2 \quad \textbf{(24)}$$

17. *Effect of the antenna dimensions upon the energy delivered to the detector by an impulse electromotive force.* The relative amounts of energy delivered by a given impulse electromotive force to two *highly oscillatory* antennas tuned to different frequencies depends greatly upon the length of the impulse relative to the natural periods of the two antennas. Thus, if the impulse lasts for an interval equal to 1/4 of the natural period of an antenna, the energy delivered to the antenna is approximately $C\,E^2$; if it lasts for 1/2 the period, the energy is $2\,C\,E^2$; if it lasts 3/4 of the period, the energy is $C\,E^2$; and if it lasts for an interval equal to the period, the energy delivered is approximately zero. Of course under these conditions it is difficult to draw conclusions as to the best antenna proportions for impulse strays lasting for varied and unknown time intervals. There are, however, two cases which may be discussed to advantage.

For the case of two different impulse strays of the same electric intensity impinging upon two different antennas and each lasting for an interval such as 1/4 or 1/2 or 3/4 of the natural period of the antenna upon which it impinges, the conclusions which have been drawn above with reference to the selective coefficient against a sustained continuous electromotive force may be applied.

This follows from the fact that the energy delivered to the detector by the sustained continuous electromotive force is $1/4\ C\,E^2$ (assuming $R_d = R_w + R_r$), while the energy delivered to the antenna by the impulse electromotive force is some multiple of this. Of the energy delivered to the antenna by the impulse stray, one half will be delivered to the detector and the other half will be dissipated as the oscillation of the antenna dies out. Therefore the following conclusion may be drawn. The selective coefficient of antenna circuits of high resonant frequency and of long time constant against those impulse strays which persist long enough to deliver to the antenna the maximum possible energy is much greater than the selective coefficients of circuits of low frequency or of short time constant.

The second simple case is the case in which a given impulse "stray" impinges upon antennas tuned to different frequencies, and in which the natural periods of both antennas are ten or more times as long as the time interval (T_1) of the impulse. In this case the energy delivered to the antennas is given approximately by the expression

$$W = 1/2\,C\,E^2\,4\,\pi^2 f_r^2\,T_1^2 \quad \textbf{(25)}$$

If we substitute in this expression the values of $1/2\,C\,E^2$ as given in Table VI for the four classes of antennas, we arrive at the following expression for the selective coefficient against impulse voltages of very short duration

S_c against impulse voltages of very short duration

$$= \frac{b\,T_e\,T_c}{2\,T_1^2} \quad \textbf{(26)}$$

in which,

T_e is the Morse dot interval

T_1 is the length of the voltage impulse

T_c is the circuit time constant, and

b is a factor whose value depends upon the relative length of T_e and T_c, approaching unity as T_e/T_c becomes greater and greater. (The values of b may be taken from Curve E of Fig. 6).

This expression shows that the selective coefficient against such an impulse varies directly as the length of the time constant of the circuit.

The expression is independent of the resonant frequency of the circuit, and this is apt to be misleading. It must be borne in mind that this expression applies only to an impulse which lasts for a short decimal part of the natural period of the antenna. If we compare the effect of two impulses, each of which lasts for the same *decimal part* of the natural period of the antenna in which the impulse is impressed instead of for the same interval of time, this expression likewise shows that the selective coefficient varies directly as the square of the natural frequency, because T_1 now varies inversely as the frequency.

From an inspection of the expressions for the selective coefficients, namely, equations 7, 23, 24, and 26, the following conclusions may be drawn. The selective coefficient of an antenna whether against a sustained alternating electromotive force which is detuned by a given *percentage* of the resonant frequency, or against a continuous "stray" electromotive force, or against an impulse voltage which lasts for a given small decimal part of the natural period of the circuit, varies directly as the square of the resonant frequency of the antenna. Against a sustained detuned alternating e. m. f., the selective coefficient varies directly as the square of the time constant of the antenna. Against continuous and impulse voltages, the selective coefficient apparently varies directly as the first power of the time constant, but if in different circuits the time constant is always made equal to 0.02 of the interval of excitation, the selective coefficient in reality varies directly as the square of the time constant, or as the square of the interval of excitation. (See equations 13 and 14.)

18. *Effect of the unavoidable departures from resonance upon the power received.* In the determination of the selective coefficients in the preceding pages,

the receiving circuit has been assumed to be resonant to the correspondent station. In the every day operation of two stations it is, of course, impracticable to keep the receiving station exactly resonant to the sending station, because of slight unavoidable variations in the sending frequency and in the constants of the receiving circuit. If the receiving circuit is not exactly resonant to the impinging waves, the power received from the correspondent station is reduced, and the selective coefficient against the interferent source is thereby decreased. A high selective coefficient is obtained by making the time constant of the circuit long, or by making the circuit highly oscillatory, but it is evident that after a circuit has been made so highly oscillatory that the unavoidable departure from the condition of resonance gives rise to a net or residual reactance which is greater than the circuit resistance, then practically nothing is to be gained by making the circuit more highly oscillatory. Any further decrease in the circuit resistance will reduce the power received from the interferent and correspondent sources at substantially the same rate.

This question arises: Is it practicable to hold the frequency of the sending station constant enough, or to keep the receiving station tuned closely enough, to attain as high a selective coefficient as the other requirements will permit? In answering this let us assume, somewhat arbitrarily, that the permissible detuning is such as to make the net reactance $(X_L - X_c)$ equal to the resistance of the receiving circuit. Under these conditions the impedance to the correspondent frequency will be $\sqrt{2}$ times the circuit resistance, the power received from the correspondent station will be one-half as great as at exact resonance, and the selective coefficients against interferent sources will be one-half as large as at exact resonance. If the detuning is 1/2 as great as above assumed, the power received from the correspondent station is cut down to 0.8 of the power at exact resonance, while if the detuning is twice as great as assumed, the power is cut down to 1/5 of the power at exact resonance.

If the frequency is P_d decimal parts high or low, the inductive reactance X_L is P_d parts higher than the resonant value, and the capacity reactance X_c is P_d parts lower than the resonant value, or vice versa, and the net reactance is,

$$X_L - X_c = 2\, P_d\, X_L$$

Under the assumption made above, the permissible detuning is such that

$$(X_L - X_c) \text{ or } 2\, P_d\, X_L = R$$

$$\text{or} \quad 4\, \pi\, f_r\, L\, P_d = R$$

$$\text{but} \quad T_c = \frac{2\, L}{R}$$

Eliminating L and R between the above equations, the permissible detuning P_d is,

$$P_d = \frac{1}{2\, \pi\, f_r\, T_c} \text{ parts} \tag{27}$$

$$= \frac{1}{2\, \pi\, T_c} \text{ cycles} \tag{27a}$$

That is, the permissible detuning if expressed in decimal parts (or in per cent) is inversely proportional to the resonant frequency and to the time constant of the circuit, and if expressed in cycles is inversely proportional to the time constant. We have seen that a time constant of 0.01 second is desirable. Substituting this value in equation (**27**), the permissible detuning in a circuit having a time constant of 0.01 seconds is found to be 15.9 cycles per second. No matter what the resonant frequency may be, the permissible detuning (as herein defined) in a circuit having a time constant of 0.01 second is 15.9 cycles per second. Now a detuning of 15.9 cycles per second means a permissible detuning of 0.1 of one per cent at a resonant frequency of 15,000 cycles, but of only 0.003 of one per cent at 500,000 cycles. While circuits may be held in tune as closely as 0.1 of one per cent, it is questionable whether it will be found feasible to hold a sending and receiving station as closely in tune as 0.003 of one per cent.

The conclusion to be drawn is that the impracticability of keeping the receiving and sending stations closely enough in tune will establish a limit above which it is not feasible to increase the selective coefficient of the receiving circuit.

19. *Conclusions relating to the plain series antenna for receiving purposes.* The desirable features of a radio communicating system are summarized below in the order of the more complex relations first. The conclusions pertain mainly to the properties of the plain receiving antenna.

Item 1. A radio communication system may be divided into three parts,

The receiving station
The transmission medium
The sending station

Item 2. The desirable features of the receiving antenna in itself are,

a. A high selective coefficient against interferent sources: that is, the ratio of the power or energy received from the correspondent station to the power or energy received from the interferent source should be as high as possible.

b. High directive efficiency: that is, the ratio of the power which could be abstracted by a receiving antenna with negligible wasteful resistance to the power streaming across the hemisphere on which the receiving antenna is located should be as high as possible. The "directive efficiency" is directly proportional to the square of the wave length.

c. High abstractive factor: that is, the ratio of power abstracted by the actual antenna to the power

which could be abstracted by the hypothetical antenna of zero wasteful resistance, should be as high as possible. The abstractive factor equals $1/k$.

Item 3. The desirable feature in the transmission in itself is high transmission efficiency: that is, the ratio of the power streaming across the hemisphere upon which the receiving antenna is located to the power radiated from the sending station should be as large as possible. This ratio will be called the "transmission efficiency."

Item 4. The desirable feature in the sending station in itself is that the cost of radiating power per kw-hr. shall be low.

Conclusions Relating to the Selective Coefficient

Item 5. The expression for the steady state selective coefficient in terms of the dimension of the antenna is,

$$S_c = \frac{9\, p_d^2\, S^6}{64\, k^2\, \pi^4\, a^2\, h^2\, f_r^6} \tag{5}$$

This expression would indicate that to obtain a high selective coefficient, the operating frequency should be low and the dimensions of the antenna small. While this conclusion would be correct for a radio power transmission system, operating with an uninterrupted flow of power, it is grossly erroneous for a make and break communication system. In a dot and dash communicating system it is not permissible to decrease the dimensions and the frequency indefinitely, because with this decrease the time constant of the circuit increases, and a condition may very readily be reached in which the time constant of the circuit far exceeds the Morse dot interval. Under this condition, the current at the resonant frequency has only time to build up to a small fractional part of the full or steady-state value, and the above equation fails to correctly express the *Morse-dot-interval-selective-coefficient*. Accordingly, the conclusions drawn from equation (5) should be discarded and the selective coefficient should be expressed in terms of the resonant frequency and the time constant as in the following item.

Item 6. The expressions for the selective coefficients in terms of the resonant frequency and the time constant of the antenna are as follows:

S_c for steady-state against a detuned frequency

$$= (2\, \pi\, f_r\, p_d\, T_c)^2 \tag{7}$$

S_c for interval of excitation against a detuned frequency

$$= 0.8\, (2\, \pi\, f_r\, p_d\, T_c)^2 \text{ if } T_c = .2\, T_e \tag{13}$$

S_c against a continuous e. m. f.

$$= 2\, \pi^2\, b\, T_e\, f_r^2\, T_c \tag{23}$$

S_c for first cycle against a continuous e. m.f.

$$= \pi^2\, b\, T_c^2\, f_r^2 \tag{24}$$

S_c against a very short impulse

$$= \frac{b\, T_e\, T_c}{2\, T_1^2} \tag{26}$$

These equations indicate that to obtain a high selective coefficient the resonant frequency should be high and the time constant of the antenna as long as possible, subject to the limitations cited below in Items 7, 9, 10.

The selective coefficient cannot be materially increased by making the time constant longer than the interval of excitation. The longest time constant permissible in sustained wave reception equals 0.2 of the interval of excitation.

Item 7. To provide for intervals of silence between the dots and dashes, the time constant of the antenna should not exceed 0.2 of the Morse space interval, or at a sending speed of thirty words per minute the time constant should not exceed 0.01 second.

Item 8. In so far as the resistance of the tuning inductance is concerned, it is feasible to make the time constant of the receiving antenna as long as .01 second.

Item 9. The relation between the time constant and the frequency and dimensions of the antenna is given in equation (6)

$$T_c = \frac{3\, s^3}{16\, \pi^3\, k\, a\, h\, f_r^4} \tag{6}$$

To obtain a long time constant requires the use of a low resonant frequency or of an antenna of small dimensions and of relatively low wasteful resistance. To obtain a time constant as long as .01 second, or longer, there is no difficulty whatsoever: it is only necessary to make the antenna small enough. Moreover the smaller the antenna dimensions, the easier it is to make the wasteful resistances negligibly small, or to make (k) approach the value for 100 per cent abstractive factor, namely 1.

On the other hand, to build a receiving antenna having a natural time constant *as short as* .01 *second* at the lower frequencies—30,000 cycles or less,—is quite costly, although such an antenna is comparatively inexpensive for the higher frequencies,—120,000 cycles or higher. For illustrations of the sizes see Tables III and IX. At 30,000 cycles the Darien antenna has a time constant of .0042 sec. if $k = 2$. That is, its height cannot be reduced to less than .0042/.01 or 42 per cent of its present height without increasing its time constant beyond .01 sec. At 120,000 cycles the 10 meter antenna having 5 per cent of the area of the Darien equivalent antenna has a time constant of .0047 second. For a time constant of .01 sec. this ten meter antenna needs to have an area of only 2.5 per cent of the Darien equivalent, or a radius of only 36 meters.

The conclusion is that an antenna with a time constant as short as .01 second is very expensive for the lower frequencies.

Item 10. The impracticability of holding the sending frequency and the natural frequency of the receiving antenna constant enough establishes a limit above which it is not feasible to increase the selective coefficient by increasing the time constant and the frequency.

The permissible detuning, which has been arbitrarily taken as the detuning which will cut down the correspondent power to one-half of the full resonant value, may be computed by the equation

$$P_d = \frac{1}{2\,\pi\,f_r\,T_e}\text{ parts} \tag{27}$$

$$P_d = \frac{1}{2\,\pi\,T_e}\text{ cycles} \tag{27a}$$

The permissible detuning if expressed in cycles per second is independent of the resonant frequency at which the system is operated, and depends only upon the time constant of the antenna. If the time constant is 0.01 second, the permissible detuning is 15.9 cycles per second. At a frequency of 120,000 cycles per second, this is a detuning of only 0.013 of one per cent. This value (0.00013) may tentatively be accepted as a limit below which it is not feasible to hold the detuning of the correspondent station. Table VII is a brief tabulation of the conditions which tend to set the limits for the time constant of the receiving antenna.

Conclusions as to the Directive Efficiency of the System of Transmission

Item 11. The greatest power that the antenna can deliver to the detector is $\left(\frac{3}{16\,\pi\,k}\right)$ (approximately 0.06, if $k = 1$) of the power streaming across a "wave-length" square of the hemisphere on which the receiving antenna is located, unless resistance neutralization is resorted to.

The directive efficiency of the system of radio transmission varies inversely as the square of the resonant frequency. From the point of view of directive efficiency, the operating or resonant frequency should be low.

$$\text{Power to (detector)} = \frac{3}{16\,\pi\,k}\,(s\,\lambda^2)\,(\tfrac{1}{2}\,p_o\,F_m^2) \tag{18}$$

$$D_e = \frac{9\,\lambda^2}{64\,\pi^2\,r^2}$$

Conclusions as to the Power Abstractive Factor of the Antenna

Item 12. The power abstractive factor of the antenna is the ratio of the energy delivered to the detector to the energy which might have been delivered to the detector if the wasteful resistance R_w were zero, and the detector resistance R_d were equal to the radiation resistance R_r. If, as in the discussion, the detector resistance is made equal to $(R_w + R_r)$, and if the ratio of $(R_w + R_r)$ to R_r is designated by k, the abstractive factor is $1/k$. At the higher frequencies abstractive factors of fifty per cent may be obtained. The abstractive factors will necessarily be lower at the very low frequencies. Very low abstractive factors may be warranted at the lower frequencies because of the fact that the selective coefficient may be made to have the same value at the low abstractive factor as at the high factor. (See Item 15).

$$A_f = 1/k \tag{22}$$

Conclusions Relating to the Transmission Efficiency

Item 13. The only available information relating to the absorption losses in transmission, or to the transmission efficiency, is embodied in Austin's formula; namely, the power P streaming across unit area near

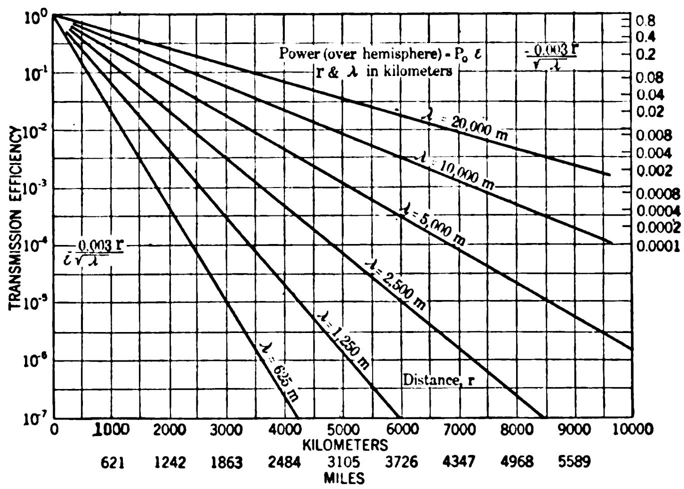


Fig. 9—Relation Between Transmission Efficiency and Distance

the ground at the distance r from the sending station is

$$P = P_0\,\epsilon^{\frac{-0.003r}{\sqrt{\lambda}}} \tag{28}$$

in which P_0 is the power which would stream across unit area near the ground were there no transmission losses and no refraction, and r and λ are expressed in km.

From this the transmission efficiency (T_r) is

$$T_r = \epsilon^{\frac{-0.003r}{\sqrt{\lambda}}} \tag{29}$$

This formula should be used with many reservations, because it is based upon meager data of a kind which it is extremely difficult to gather and to interpret.

The transmission efficiencies for different wave lengths and distances of transmission have been plotted in Fig. 9. These curves bring out the gre merit of the lower frequencies for the longer trans-

mission distances. For example, in a 6000 km. (3726 mile) transmission, the transmission efficiency for a wave length of 10,000 meters (30,000 cycles) is $3.4\ 10^{-3}$, while for a wave length of 1250 meters (240,000 cycles) the transmission efficiency is only 10^{-7}.

Conclusions Relating to the Cost of Power Radiated from the Sending Station

Item 14. With the developments which are still taking place in methods of generating high frequencies, it cannot be determined whether it will eventually be cheaper *to deliver to the antenna* power at the higher or at the lower frequencies.

TABLE VII
CONDITIONS WHICH TEND TO SET THE LIMITS FOR THE TIME CONSTANT OF THE CIRCUIT.

Tending to set a limit to the length of T_c	Tending to set a limit to the shortness of T_c
To provide for intervals of silence between the dots, the time constant cannot be allowed to exceed 0.2 of the Morse space interval, that is, cannot exceed 0.1 sec. at 30 words per minute.	The selective coefficient varies directly as the second power of the time constant, therefore the time constant should be long.
The impracticability of holding the sending and receiving stations more closely tuned than P_d = .00013 decimal parts, makes it of no advantage to make T_c larger than given by $\frac{1}{2\pi f_r T_c} = .00013$	The volume under the antenna (the $a\,h$ product) necessary to reduce the time constant to .01 sec. varies inversely as the time constant and the fourth power of the frequency. To obtain a short time constant at the low frequencies requires an enormous antenna.

TABLE VIII
MERITS OF HIGH VERSUS LOW FREQUENCIES

Merits of high	Merits of low
High frequency leads to a high selective coefficient S_c varies as f_r^2	The directive efficiency varies inversely as the square of the frequency D_e varies as $\frac{1}{f_r^2}$
The higher the frequency, the smaller may the volume of the receiving antenna be without causing the time constant to exceed .01 second. $a\,h = \frac{3\,S^3}{16\,\pi^3\,k\,T_c\,f_r^4}$	The permissible detuning, in decimal parts, is greater at the lower frequencies. $P_d = \frac{1}{2\,\pi\,f_r\,T_c}$
The abstractive factor may be made somewhat higher at the higher frequencies.	The transmission efficiency for long distances is far higher at the lower frequencies than at the higher.
The cost of radiating power per kw. is far lower at the higher frequencies. $P = \frac{2\,\pi^2\,a^2\,f_r^4\,E^2}{45\,s^4}$	

However, the charge per kw. for radiating power *from* the antenna which is entailed by the cost of the antenna itself is far higher at the lower frequencies than at the higher. This follows from the fact that the power which can be radiated from an antenna of given dimensions *at a given voltage* varies as the fourth power of the frequency. Putting the matter in another way, to radiate a definite amount of power from an extended platform antenna at a given voltage, the area of the platform must be inversely proportional to the square of the frequency. For example: With the key tied down the Darien antenna at 100 r. m. s. kv. will radiate 3,080 kw. at 120,000 cycles, but only 12 kw. at 30,000 cycles. Herein is low frequency at a disadvantage.

Conclusions Relating to the Figures of Merit of the Frequencies When Receiving With Plain Antenna Circuits

Item 15. In Table VIII the merits of high versus low frequencies are tabulated.

In Table IX is a compilation of data relating to the merits of the different frequencies for different distances of transmission. In the first and second lines of this table are tabulated the frequencies and wave lengths to which the following data pertains.

In line 3 is given the radius which an extended circular platform antenna must have in order to radiate 5 kw. at 100 r. m. s. kv. with the key held down continuously.

In line 4 is given the height at which an upper network of the radius specified in line 3 must be mounted in order that the time constant shall be 0.01 second, assuming that $k = 2$, or that the total resistance is equal to four times the radiation resistance of the network. If the height is made greater, the time constant will be shortened, T_c varies as $1/h$. In the sending station, there is no reason why the time constant should not be shorter than 0.01 second. However, increasing the height will not permit of any reduction in the radius of the sending network if 5 kw. is to be radiated at 100 kv., unless the height is of the same order as or greater than the radius of the network. In the receiving station there is no reason why the radius should be as large as given in line 3. All that is required is that the $(a\,h)$ product shall have the same value as for lines 3 and 4. At the higher frequencies, the antenna of both the sending and receiving stations would be much smaller in radius and higher than the figures given in lines 3 and 4.

In line 5 is given in decimal parts the permissible detuning between the correspondent stations: that is, the detuning which will, when the receiving circuit has a time constant of 0.01 second, cause the correspondent power to drop off to fifty per cent of the full resonant value. The close tuning required at 480,000 and 240,000 cycles may be unattainable. If these values are unattainable, the selective coefficients given

in lines 6 and 7 for the two higher frequencies are also unattainable, and should not be greater than the selective coefficient for 120,000 cycles.

In line 6 is given the selective coefficient against sustained continuous voltage strays of the same electric and magnetic intensity as the correspondent waves.

In line 7 is given the selective coefficient to sustained waves detuned by one per cent. As previously noted under line 5, the high selective coefficients for 240,000 and 480,000 cycles are unattainable unless the resonant frequency of the sending and receiving circuits can be held as close as specified in line 5.

Hence if we are concerned only with the absolute amount of power received from the correspondent station, the continued product
(transmission efficiency) × (directive efficiency) × (abstractive factor)
may be characterized as the "Figure of Merit of the frequency for power transmission purposes with antenna costs neglected." Under these conditions the comparison between the frequencies reduces to this: The merits of the low frequency are the higher transmission and higher directive efficiencies: its demerits are, the greater volumes of the antennas which must be used at both the sending and receiving

TABLE IX
FIGURES OF MERIT OF THE FREQUENCIES WHEN RECEIVING WITH PLAIN ANTENNA CIRCUITS: ANTENNA COSTS ARE NEGLECTED.

1	Frequency		480,000	240,000	120,000	60,000	30,000	15,000
2	Wave length ... meters		625	1250	2500	5000	10,000	20,000
3	Radius for radiating 5 kw. at 100 r. m. s. kv. ... meters		11.5	23.	46.	92.	184.	368.
4	Height for a T_c of .01 sec. with above radius ($k = 2$) meters		.36	1.44	5.76	23.	92.	368.
5	Permissible detuning in decimal parts if $T_c = .01$ second		.00003	.000065	.00013	.00026	.00052	.001
6	Selective coefficient against continuous voltages		1024 ( )	256 ( )	64 ( )	16 ( )	4 ( )	1 (1.810[6])
7	Selective coefficient against alternating e.m.f.s detuned by 1 %		1024 ( )	256 ( )	64 ( )	16 ( )	4 ( )	1 (89)
8	Abstractive factor		.5	.5				
9	Directive efficiency r in km		1/1024 ( )	1/256 ( )	1/64 ( )	1/16 ( )	1/4 ( )	$\left(\frac{5.7}{r^2}\right)$
10		500 km.	.15	.28	.40	.50	.60	.70
11	Transmission efficiency	1000 km.	.02	.07	.15	.28	.40	.50
12	(No great reliance should be placed on these	2000 km.	.0005	.005	.02	.07	.15	.28
13	transmission efficiencies)	4000 km.		.00002	.0005	.005	.02	.07
14		8000 km.			.0000003	.0002	.0005	.005

In line 8, the abstractive factor has been listed for the higher frequencies only, as approximately fifty per cent. It will be much lower at the lower frequencies.

In line 9 is given the directive efficiency of the receiving antennas.

In lines 10 to 14 is given the transmission efficiency of the different frequencies for different transmission distances from 500 to 8000 km.

If two sending stations are each radiating the same amount of power but at different frequencies, and each station is sending to its own receiving station, located, say, 4000 km. away, the ratio between the power inputs to the two receiving stations is the ratio between the values of the following continued products for each system.
Power input = (Power radiated) × (transmission efficiency) × (directive efficiency) × (abstractive factor)

stations and the somewhat lower abstracting and radiating efficiencies even with antennas of the larger volume.

In a radio communication system the item of importance is not the absolute amount of power received from the correspondent station, but the relative amounts of power received from the correspondent station and from the interferent sources. Again assume that two sending stations are each radiating the same amount of power but at different frequencies, and each station is sending to its own receiving station, located, say, 4000 km. away. The power per unit area streaming past each receiving station is proportional to the transmission efficiency for the particular frequency. That is to say, the square of the electric intensity at each antenna or the square of the voltage induced per unit length in the antennas of each receiving station, is proportional to the transmission efficiency for the frequency. Whereas the electric

intensity set up by the interferent sources must be taken to be the same at one station as at the other. Hence it follows that if the *selective coefficients of the two receiving antennas had the same numerical value* the ratio between the power ratios of the two receiving stations would be proportional to the transmission efficiencies.

$$\frac{\text{Correspondent power for freq. 1}}{\text{Interferent power for freq. 1}} : \frac{\text{Correspondent power for freq. 2}}{\text{Interferent power for freq. 2}} -$$

= Transmission efficiency for freq. 1 : Transmission effic'y. for freq. 2,

But for each receiving station the ratio between the correspondent and interferent power abstracted from waves of the *same intensity* is given by the value of its selective coefficient. Hence it follows that if the selective coefficients are not identical in value, the ratios are as follows:

$$\frac{\text{Correspondent power for freq. 1}}{\text{Interferent power for freq. 1}} : \frac{\text{Correspondent power for freq. 2}}{\text{interferent power for freq. 2}}$$

$= (T_r)\ (S_c)$ for freq. 1: $(T_r)\ (S_c)$ for freq. 2

Therefore for the purpose of receiving through troublesome interference, the product of

(transmission efficiency) × (selective coefficient)

may be characterized as the "Figure of Merit of the frequency (with antenna costs neglected) *when receiving with a plain series antenna.*" Under these conditions the comparison between the frequencies reduces to this: The merit of the low frequency is its higher transmission efficiency: its demerits are its lower selective coefficient, the greater volumes of the antennas which must be used at the sending and receiving stations, and the lower radiating efficiency of the sending station.

At this point we discontinue the discussion of the plain antenna circuit, because coupled circuits must be used to obtain higher selective coefficients. When the detector is associated, not directly with the antenna circuit, but with a tuned secondary or tertiary circuit, the selective coefficient of the system against detuned alternating electromotive forces varies as the fourth or the sixth power of the resonant frequency. Hence the higher frequencies have an additional advantage which tends to shift the optimum frequency toward the higher values. This discussion of the properties of the antenna circuit is a necessary preliminary to the study of the possibilities of the antenna combined with additional sifting circuits.

COAL SUPPLY

The month of November has marked the passing of most of the Interstate Commerce Commission's restrictive orders on the use and transportation of coal. In general, these orders have produced the results for which they had been issued and the distribution of coal has for the most part returned to nearly normal conditions. The lifting of the late priority order for instance had the effect of releasing at least one-half of the 4000 cars which had been dumped daily at lower Lake ports. During the latter part of the time that the Lake order was in effect the refusal of the Northwest to buy resulted in a large number of cars being held underloaded. With the lifting of the order, however, this accumulation of coal on cars was hurried into distribution with the result that very substantial relief was given in the Middle West. After coal began to move in this way its rate of transportation was soon slowed down however, because there were no automatic unloading arrangements such as there had been at the Lake Port.

The National Committee on gas and electric service is working in cooperation with the Interstate Commerce Commission and a number of emergencies have been taken care of by them. This committee is composed of representatives of the operators of the railroads and of public utilities. It is understood that they will have increased difficulties in meeting the situation as the effects of the Interstate Commerce Commission's service orders are removed. It is expected that the principal difficulty will be in supplying the public utilities that have small stocks of coal which cannot be readily replenished if extremely bad weather sets in.

There is evidence that spot coal will continue to sell for some time to come at a higher figure than most contracts. There will be a resultant tendency to sell on the open market rather than comply with the terms of the contract. Although it is pointed out that between 80 and 90 per cent of the requirements of the gas and electric companies are covered by contracts, it may be some time before they are able to build up their reserves however.

In the event that the East and Middle West experience severe winter weather before the first of the year it is feared that a large number of public utility plants will be forced to suspend operation due to the fact that they have no reserve stock of coal. Since through the control of the coal supply the Interstate Commerce Commission has the responsibility of public utility service throughout the country, the situation has been carefully laid before them by the utility interests and their optimistic views will probably be effected accordingly.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

A. I. E. E. AKRON-CLEVELAND MEETING, JANUARY 14, 1921

The 366th meeting of the A. I. E. E. will be held in Akron and Cleveland, Ohio, on January 14th, 1921. According to the tentative plans which are being developed by the Meetings and Papers Committee, members attending the meeting will assemble in Akron, where an inspection of the Goodrich Rubber Plant will take place during the afternoon. Special cars will take the party from Akron to Cleveland in time for dinner in Cleveland, after which there will be a technical session during the evening.

The Board of Directors will hold its regular monthly meeting at 9.30 a.m. in Akron, and any committees that wish to hold meetings that day are expected to hold them in Akron during the morning.

The general subject of the technical session will be "Rubber Mill Electrification." Several papers on different phases of this subject will be presented under the auspices of the Industrial Power Committee. The program in detail will be printed in the January JOURNAL. The general arrangements of the meeting will be under joint auspices of the Akron and Cleveland Sections.

A. I. E. E. MIDWINTER CONVENTION

The Midwinter Convention, according to the original plans of the Meetings and Papers Committee, was to have been held February 23-25, 1921, as announced in the November JOURNAL. It has been found advisable, however, to advance the time of holding the Convention, and at the suggestion of the Board of Directors the Midwinter Convention will be held February 16-18, a week earlier than originally planned.

NEW YORK SECTION MEETING, DECEMBER 3

A joint meeting of the New York Section of the A. I. E. E., Management and Metropolitan Sections of the A. S. M. E., and the Taylor Society will be held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, December 3rd, at 8 p. m. The general subject of the meeting will be "The Long Day in the Steel Industry," and three addresses will be given as follows: *Introductory Remarks*, by Fred J. Miller, President of the A. S. M. E., who will preside; *The Three-Shift System in the Steel Industry*, by Horace B. Drury, recently with the Industrial Relations Division, U. S. Shipping Board; *The Point of View of the Manufacturer*, the speaker to be announced later.

Following the addresses a general discussion will take place, led by Robert B. Wolf, Consulting Engineer, New York, and several others prominent in the industry.

This meeting takes the place of that previously announced on "The American Power Problem," which subject has been unavoidably postponed.

FUTURE SECTION MEETINGS

Chicago.—December 17, 1920, Western Society of Engineers. Papers: "Economic Aspects of the Light Weight Safety Car," by H. A. Johnson, Organizing Engineer, Chicago, N. S. and Milwaukee Railway; "Train Operation on Surface Lines," by F. B. Way, Vice-President and General Manager, Milwaukee Elec. Railway & Light Company; "Substation Operation," by Charles H. Jones, Electrical Engineer, Chicago, North Shore & Milwaukee Railway.

January 24, 1920. Subject: "Research, A National Issue and How to Meet it in a Practical Way."

Cleveland.—December 21, 1920. Subject: "The Purchase and Use of Electric Motors from the Owners' Standpoint." Speaker: Mr. James Burke.

Lynn.—December 8, 1920. Subject: "Super-power Zone." Speaker: Mr. William S. Murray.

Pittsburgh.—December 14, 1920. Subject: "Wireless Development." Speaker: Mr. A. F. Van Dyck, General Electric Company.

Pittsfield.—December 16, 1920. Subject: "Ice Formation and Its Preventions." Speaker: Mr. John Murphy, Ottawa, Ontario.

January 20, 1921. Subject: "On the Frontiers of the Universe, or An Evening With the Stars." Speaker: Mr. B. R. Baumgardt, Lecturer, Los Angeles and New York.

Portland, Ore.—January 10, 1921. Subject: "Progress in the Electrical Industry on the Pacific Coast." Speaker: Mr. Robert Sibley.

Seattle.—December 21, 1920. Subject: "Recent Developments in Radio Engineering." Speaker: Mr. F. G. Simpson, Vice-President and General Manager, Kilbourne & Clark Mfg. Co.

CHICAGO MEETING

The Institute held its 365th meeting on Friday, November 12, in Chicago, under the auspices, jointly, of the Chicago Section and the Protective Devices Committee, with the Electrical Section of the Western Society of Engineers participating. The program as announced in a previous issue of the JOURNAL was carried out as arranged.

The following committees held meetings in the afternoon: Mines Committee, Membership Committee, Educational Committee, Protective Devices Committee. The Board of Directors held its regular monthly meeting at 3:00 o'clock at the headquarters of the Western Society of Engineers, where most of the committee meetings were held.

At the informal dinner at the City Club, Chairman J. R.

Bibbins of the Chicago Section presided, and brief addresses were made, both relating to the Federated American Engineering Societies, by President Berresford of the A. I. E. E., and President Copeland of the Western Society of Engineers.

President Berresford presided at the opening of the technical session during the presentation of Mr. Roper's paper, after which he turned the meeting over to Mr. Roper, Chairman of the Protective Devices Committee, who presided during the remainder of the session. The following papers were presented: *Studies in Lightning Protection on 4000-Volt Circuits-II*, by D. W. Roper, of the Commonwealth Edison Co.; *Lightning Arrester Spark Gaps-II*, by C. T. Allcutt, of the Westinghouse Electric & Mfg. Co.; *Life and Performance Tests of O F Lightning Arresters*, by N. A. Lougee, of the General Electric Company; and *Electrostatic Condensers*, by V. E. Goodwin, of the General Electric Co. All four authors were present and presented their papers in person.

Inspection trips were held on Saturday, to the Mark, Ind. Plant, Steel & Tube Company of America; the Automatic Substation of the Chicago, North Shore & Milwaukee Railway, Lake Bluff, Ill., and the Northwest Station, Commonwealth Edison Company.

A. I. E. E. DIRECTORS MEETING

NOVEMBER 12, 1920

The regular monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the headquarters of the Western Society of Engineers, Chicago, on Friday, November 12, 1920, at 3.00 p. m.

There were present: President A. W. Berresford, Milwaukee; Vice-Presidents Charles S. Ruffner, New York, Charles Robbins, Pittsburgh, E. H. Martindale, Cleveland; Managers Wilfred Sykes, Chicago, L. F. Morehouse and E. B. Craft, New York, James F. Lincoln, Cleveland; Secretary F. L. Hutchinson, New York.

The Board ratified the approval by the Finance Committee of monthly bills amounting to $32,195.96.

The Secretary was authorized to remove from the membership list December 31, 1920, the names of all members in arrears for dues for the year ending April 30, 1920.

A report was presented of a meeting of the Board of Examiners held October 25, 1920; and upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 353 Students were ordered enrolled; 111 applicants were elected to the grade of Associate; 9 applicants were elected to the grade of Member.

Upon recommendation of the Board of Examiners the following Local Representatives of that Board were appointed for the present administrative year: C. L. Cory, San Francisco, Cal; L. A. Herdt, Montreal, Quebec; H. H. Humphrey, St. Louis, Mo.; D. W. Roper, Chicago, Ill.; A. M. Schoen, Atlanta, Ga.; J. F. Vaughan, Boston, Mass.

The Meetings and Papers Committee reported upon plans for future meetings including the meeting to be held on January 14, at Akron and Cleveland, Ohio, and a meeting to be held in Pittsburgh in April. Upon recommendation of the Pittsburgh Section and the Meetings and Papers Committee the Board voted to extend an invitation to the members of the Association of Iron and Steel Electrical Engineers to participate in the Pittsburgh meeting in April.

Following a brief discussion of the Annual Convention of 1921, including the present high costs of Institute's publications, the following resolutions were adopted:

RESOLVED that the attention of the Meetings and Papers and Publication Committes be called to the present financial condition of the Institute which has made necessary the omission in the budget for the present appropriation year of the sum required to complete the printing of the 1920 TRANSACTIONS; and that these committees be reminded that the appropriations for the activities within their jurisdiction for the present year are larger than ever before in the history of the Institute, but that on account of the increased costs of carrying on these activities it will be necessary for these committees to watch their appropriations very carefully, as there is little likelihood that it will be possible to grant any increase to the appropriations for the present year.

RESOLVED that the Board hereby confirms its action of last spring to the effect that the social features of the summer convention benefit and strengthen the technical interests of the Institute and the engineering profession, and reaffirms as a policy of the Institute that the principal meeting of the year for the presentation of technical papers shall be the Midwinter Convention, and that the program of the Annual Convention in June shall include only a limited number of technical papers, to be presented in not exceeding four sessions, with ample time for discussion; thus allowing time for excursions and other social features which may be arranged by the convention committee.

The following appointments of Institute representatives were made: H. H. Barnes, Jr., to Board of Trustees, United Engineering Society for term of three years commencing January 1921; E. B. Craft, to the Library Board, United Engineering Society, for term of four years commencing January 1921; H. M. Hobart, reappointed to American Engineering Standards Committee, for term of three years commencing January 1921; John Price Jackson, reappointed to Commission of Washington Award, for term of two years commencing January 1921.

The establishment of a Student Branch of the Institute at Case School of Applied Science, Cleveland, Ohio, was authorized.

Upon the recommendation of the special committee which had been appointed to consider a proposal of the Engineering Division of the National Research Council that the Institute assume sponsorship in the field of electrical engineering research in connection with the work of the Engineering Division, the Board authorized the appointment of a General Advisory Board on Electrical Engineering, of the Engineering Division of the National Research Council, which will also constitute the Institute's Research Committee.

In support of the activities of Engineering Council relative to the Patent Office, the following resolution was adopted:

RESOLVED that the Board of Directors of the American Institute of Electrical Engineers hereby endorses the resolutions adopted by Engineering Council at its meeting in Chicago relative to the desirability of obtaining adequate legislation in Congress for the support of the Patent Office, and directs that the matter be brought to the attention of the members of this Institute through publication in our monthly JOURNAL, and recommends that individual members communicate with their representatives and senators in Congress urging prompt action.

Upon request of Engineering Council for endorsement of the report of Council's Committee on Classification and Compensation of Engineers, which report had been printed some months ago in the JOURNAL, the following resolution was adopted:

RESOLVED that the Board of Directors of the American Institute of Electrical Engineers hereby endorses the report of Engineering Council's Committee on Classification and Compensation of Engineers which was published in the February 1920 issue of the JOURNAL of the A. I. E. E.

In addition to these actions many other matters relating to important activities and the general policy of the Institute were discussed. Reference to these matters may be found in this and future issues of the JOURNAL under suitable headings.

NOMINATION AND ELECTION OF INSTITUTE OFFICERS FOR 1921-1922

As provided in Section 19 of the Institute By-Laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1921, by the petition or by the separate endorsement in writing, of not less than twenty-five members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1921. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: a President and a Treasurer

for the term of one year each, ten Vice-Presidents for the term of two years each, and three Managers for the term of four years each.

At the Annual Meeting of May 1920, amendments to the Constitution were adopted, carrying out the recommendations of the Committee on Development, in its report of August 12, 1919, that the membership be grouped into geographical districts, that one Vice-President be elected from each district and that Vice-Presidents hold office for a term of two years. The recommendation for the removal of the constitutional inhibition upon the election of a Vice-President as Manager was complied with and the immediate re-election of a Vice-President to the same office provided for with provision against too extended term of office. The former inhibition upon the re-election of a President or Manager to the same office was continued.

5. Great Lakes: Illinois, Indiana, Michigan, Wisconsin.

6. North Central: Colorado, Iowa, Minnesota, Nebraska, North Dakota, South Dakota, Wyoming.

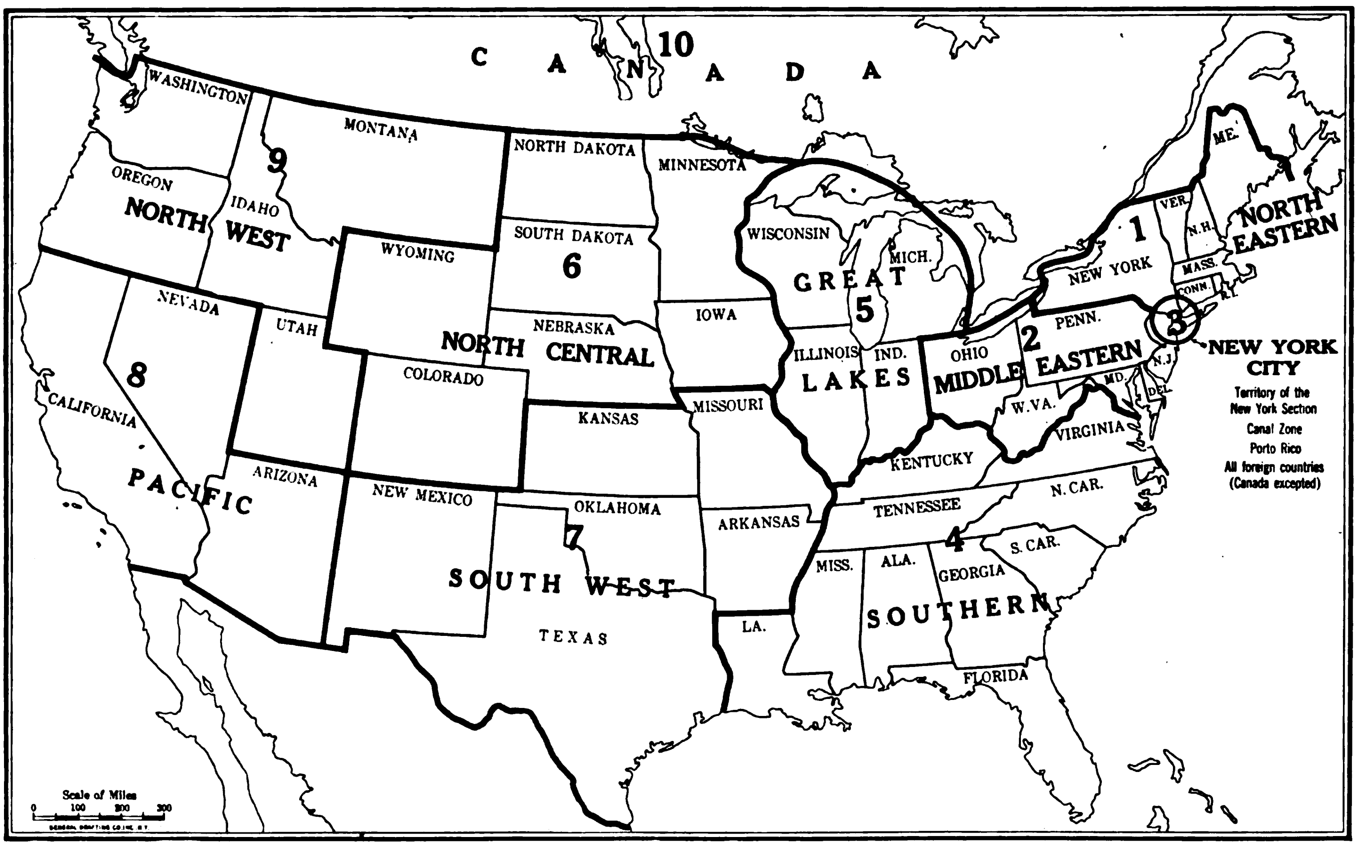
7. South West: Arkansas, Kansas, Missouri, New Mexico, Oklahoma, Texas.

8. Pacific: Arizona, California, Nevada, Hawaii, Philippines.

9. North West: Idaho, Montana, Oregon, Utah, Washington, Alaska.

10. Canada:

According to the revised Constitution one Vice-President must be elected from each geographical district but this does not debar members in one district, if they so wish, from nominating and voting for a candidate in another district. When the votes are counted the candidate for Vice-President having the largest vote in each district will be elected to that particular office for



Geographical Districts into Which the Membership of A. I. E. E. Has Been Divided for the Purpose of Electing Vice-Presidents

At the November 12 meeting of the Directors revisions of the By-Laws were adopted, including the definition of the ten geographical districts decided upon by the Committee on Geographical Divisions and Election Procedure. The ten districts defined in Section 21 of the By-Laws are, as follows:

1. North Eastern: Connecticut (exclusive of N. Y. Section territory), Maine, Massachusetts, New Hampshire, New York (exclusive of N. Y. Section territory), Rhode Island, Vermont.

2. Middle Eastern: Delaware, District of Columbia, Maryland, New Jersey (exclusive of N. Y. Section territory), Ohio, Pennsylvania, West Virginia.

3. New York City: Territory of the New York Section, Canal Zone, Porto Rico, all foreign countries (Canada excepted).

4. Southern: Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia.

that district, irrespective of the fact that he may have polled a smaller number of votes than a man standing second in another district.

For the information of members the full text of revised sections of the Constitution and By-Laws applying to Officers, nominations, elections, etc., are printed below:

CONSTITUTION

Sec. 23. The officers of the Institute shall be a President, one Vice-President from each geographical district as defined in the By-Laws, twelve Managers, a Secretary and a Treasurer.

Sec. 24. The President, the Secretary and the Treasurer shall hold office for one year, the Vice-Presidents for two years and the Managers for four years. The President and Managers shall not be eligible for immediate re-election to the same office. No Vice-President or Manager who has served continuously in one or more offices, and whose combined terms shall have aggregated six years or more, shall be eligible for immediate election to the office of Manager or Vice-President. At each Annual Meeting the President, the requisite number of Vice-Presidents to fill vacancies caused by expiration of terms, three Managers and the Treasurer shall be

elected by the membership, and their terms of office shall commence on the first of August next succeeding their election. . . . . . .

SEC. 24A. At the election of Vice-Presidents held in 1921 there shall be elected one Vice-President from each geographical district, those from the odd-numbered districts to serve for one year each, and those from the even-numbered districts two years each. All Vice-Presidents elected thereafter shall serve for two years each. In the event of a change in the geographical districts, the Vice-Presidents then in office shall complete their terms. In case of revisions of the geographical districts, the Board of Directors shall have the power to elect a Vice-President from each district not represented, to serve until the next election covering these districts.

BY-LAWS

SEC. 19. In addition to the names of the incumbents of office the Secretary shall publish on the "form showing offices to be filled at the ensuing annual election in May provided for in Article VI, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than twenty-five members, received by the Secretary of the Institute in writing by January twenty-fifth of each year; provided, however, that any candidate proposed for nomination by petition may withdraw his name by written communication to the Secretary, and any name so withdrawn prior to the printing of the form shall not be published.

The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each year's JOURNAL and shall be reproduced on the form above referred to.

SEC. 21. There shall be ten geographical districts grouped as follows: (For the balance of this Section describing districts see paragraph preceding map.)

SEC. 21A. Should the territory of any Institute Section lie in more than one geographical district as defined above, then the entire territory of said Section shall be considered as belonging to the geographical district in which the headquarters of the Section are located.

NEW YORK SECTION OF CIVIL ENGINEERS MEETS DECEMBER 15

The New York Section of the American Society of Civil Engineers has extended a special invitation to the membership of the New York Section of the American Institute of Electrical Engineers to attend a meeting on December 15th at which the subject of discussion will be "The Port of New York." The meeting will be held on the fifth floor of the Engineering Societies Building, and will be called to order at 7.45 p.m. The subject will be introduced by Mr. B. F. Cresson, and the following gentlemen have been invited, and are expected to participate in the discussion: Geo. S. Webster, F. W. Cowie, E. P. Goodrich, Murray Hulbert, Frank L. Williams, G. F. Nicholson, Geo. T. Hand, F. L. Stuart, J. J. Mantell, A. W. Robinson, John Meigs, P. A. S. Franklin, Irving T. Bush and F. T. Chambers.

THE INSTITUTION OF CIVIL ENGINEERS INVITES A. I. E. E. TO PARTICIPATE IN ENGINEERING CONFERENCE

The following letter has been received by the Secretary inviting members of the Institute to participate in an Engineering Conference, to be held under the auspices of the Institution of Civil Engineers. Members in England at the time designated are urged to accept the invitation and join in the discussion.

The Institution of Civil Engineers
Great George St., Westminster, S. W. I.
October 29, 1920.

The Secretary,
American Institute of Electrical Engineers,
New York, N. Y.

My dear Sir,

I am directed by the Council to inform you that it is proposed to hold at this Institution in the summer of next year, probably at the end of June, another general Engineering Conference—the series of which was unfortunately broken by the European War. At these Conferences which have been generally of three days' duration, questions are introduced, with a view to discussion on important problems of the day arising in or affecting the various departments of engineering, including the education and training of engineers; and in the past these discussions have enjoyed very considerable support and success.

The Council now wish me to say to you, and through you to the members of the American Institute of Electrical Engineers, that any members of your Society who may be in England at the time of the Engineering Conference referred to are cordially invited to take part in it, and to contribute to the discussion of the subjects that may be submitted at the Conference.

Yours faithfully,
J. H. T. TUDSBERRY,
Secretary.

ANNUAL MEETING OF A. S. M. E.

The American Society of Mechanical Engineers will hold its Forty-first Annual Meeting, December 7-10, 1920, in the Engineering Societies Building, 29 West 39th Street, New York. One of the features of the meeting will be a keynote session on Transportation, on December 9, at which addresses will be given as follows: *Railroads*, by Daniel E. Willard, President Baltimore & Ohio Railroad; *Railroad Feeders*, by Charles A. Morse, Chief Engineer, Chicago, Rock Island & Pacific Railroad; *Waterways*, by General Frank T. Hines; *Motor-Truck Transportation*, by Francis W. Davis, Engineer, Pierce-Arrow Motor Car Company; *Terminals*, by Col. William Barclay Parsons, Consulting Engineer, New York City; and *The New York Terminal Problem*, by Gustav Lindenthal, Consulting Engineer, New York City. The program also includes sessions of Professional Sections on Fuels, Railroads, Management, Machine Shop, Textiles and Power, which promise to be of unusual value. Incorporated in the meeting will be a memorial service in honor of Dr. John A. Brashear, Past-President of the Society. Dr. Henry Smith Pritchett, President of the Carnegie Foundation for the Advancement of Teaching, will deliver the eulogy on Dr. Brashear, on Wednesday evening, December 8.

FORTIETH ANNIVERSARY OF THE A. S. M. E.

The fortieth anniversary of the founding of the American Society of Mechanical Engineers was celebrated at a meeting held November 5, 1920, at the Engineering Societies Building, 33 West 39th Street, New York. This celebration was one of thirty-two similar meetings held simultaneously in some of the larger cities throughout the country. Messages of congratulations were received from a number of prominent men, including President-Elect Warren G. Harding, Vice-President-Elect Calvin Coolidge, Herbert Hoover, and Charles M. Schwab.

The subject of the meeting was "The Opportunity and Responsibility of the Engineer," and addresses were made by Samuel Gompers, President of the American Federation of Labor, William B. Dickson, Vice-President of the Midvale Steel and Ordnance Company, J. Herbert Case, Acting Governor of the Federal Reserve Bank Fred J. Miller, President of the Society, William L. Saunders, Past-President of the American Institute of Mining and Metallurgical Engineers, Henry R. Towne, A. P. Davis, President of the American Society of Civil Engineers, and Charles F. Scott, Past-President of the American Institute of Electrical Engineers.

ANNUAL MEETING OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

The seventy-third meeting of the American Association for the Advancement of Science, together with meetings of a large number of the national scientific societies that are associated with it, will be held in Chicago, from December 27, 1920, to January 1, 1921. Dr. L. O. Howard, Chief of the Bureau of Entomology, U. S. Department of Agriculture, who has been permanent secretary of the Association for 22 very successful years—during which time the membership has been increased

from 1,729 to about 13,000—is president-elect and will preside at the Chicago meeting. The address of the retiring president, given at the opening general session of the Association, will be by Dr. Simon Flexner, Director of the Rockefeller Institute for Medical Research.

GEORGIA CITIZENS VISIT ENGINEERING SOCIETIES BUILDING

On November 23rd about one hundred and fifty citizens of Georgia, including Governor Hugh M. Dorsey and staff, and President K. G. Matheson of the Georgia School of Technology, visited New York during their tour to many of the principal industrial centers of the country for the purpose of investigating the progress that is being made in industrial research, the ultimate object being the encouragement of research in Georgia.

Members of the party were the guests of the Merchants' Association of New York at luncheon, after which they visited the Engineering Societies Building where a brief special meeting was held in the auditorium. President J. V. Davies of the United Engineering Society extended a welcome and briefly explained the scope of the national engineering societies and their relation to research work through the Engineering Foundation, The National Research Council, Engineering Council, Engineerings Societies Library, etc. Governor Dorsey responded and brief addresses were also made by Professor Walter Rautenstrauch of Columbia University, President Matheson of the Georgia School of Technology, Director Harrison W. Craver of the Engineering Societies Library, Mr. Phinehas V. Stephens and others, after which the party was escorted through the building in small groups by Reception Committees representing the national societies. The Institute's representation consisted of: Messrs. C. S. Ruffner, Chairman, H. H. Barnes, Jr., E. B. Craft, H. H. Norris, H. A. Pratt, W. I. Slichter and Secretary Hutchinson.

In the evening the Georgians were the guests of the Georgia Society at dinner, after which they returned to their special train, which left at midnight for Washington.

SHELDON MEMORIAL EXERCISES

Interesting and impressive exercises in memory of Dr. Samuel Sheldon were held in the main auditorium of the Engineering Societies Building on the evening of November 17, and were well attended in spite of inclement weather.

The meeting was conducted by President Arthur W. Berresford, who as a graduate under Dr. Sheldon at the Brooklyn Polytechnic Institute. class of '92, was able to give a number of personal reminiscences in an admirable address, which referred briefly also to the work of his predecessor in various A. I. E. E. capacities and as an efficient president in 1906-7.

Dr. A. E. Kennelly, Professor of Electrical Engineering, Harvard and Massachusetts "Tech," gave a masterly address dealing principally with Dr. Sheldon's work as an engineer, author and educator. It is to be remembered that prior to the work begun by Dr. Sheldon in Brooklyn in 1889, courses of study in America in electrical engineering were limited and in a formative, constructive stage. The classes, the profession, the industries had all grown in an extraordinary manner; and Dr. Sheldon had kept abreast of it all down to the very last. Dr. Kennelly in speaking of the influence thus exerted made a charming comparison with the ever widening waves emanating from a great radio source of energy. He dwelt also upon the very lovable human qualities of their friend and colaborer.

Mr. Bancroft Gherardi was to have spoken on behalf of the United Engineering Society and its allied agencies with which Dr. Sheldon was associated for several years, but was called out of town on very important business. From a thousand miles away he sent a message to the meeting by long distance telephone expressive of his sentiments as a friend and admirer of Dr. Sheldon and as one who had been glad to be among his students at the Polytechnic.

President W. N. Dickinson of the New York Electrical Society made a very interesting address giving some of his own personal reminiscences of study at the "Poly" under the Sheldon regime, and summing up the year's work of his predecessor as head of the oldest American electrical engineering society in 1902-3.

Such topics were authoritatively considered then as wireless telegraphy, the steam turbine, radio active substances, motor drive of machine tools, electrical insurance conditions; A. I. E. E. high pressure standards electric elevators and submarine cables.

Dr. William H. Nichols, chairman of the board of trustees of the Brooklyn Polytechnic, made a forceful speech and spoke in glowing terms of "Sammy" as all loved to call him, emphasizing the Doctor's good work and influence, and insisting that means should be found to carry them into the future while perpetuating a memory that could not be allowed to die.

Mr. T. C. Martin on behalf of the Engineers Club and fellow members there touched upon the pleasant memories of Dr. Sheldon in the Club and his enjoyment of its friendly relationships and social intercourse. As chairman of the Sheldon Memorial Committee, Mr. Martin also drew attention to the formal resolutions of regret adopted and forwarded by the American Institute of Electrical Engineers, the New York Electrical Society, the United Engineering Society, the Engineering Foundation and the Library Board. He also stated that the Committee had received a large number of appreciations, including three from Past-Presidents Chas. F. Scott, Paul M. Lincoln and Calvert Townley. Several letters, he said, as instanced by one that he read, had been received urging the creation of a permanent memorial, and expressing the desire to contribute. Referring to the fact that Dr. Sheldon had begun his student work abroad under Kohlrausch in determining the ohm, he expressed the belief that Dr. C. O. Mailloux as President of the International Electrotechnical Commission, might fitly give a broader aspect to their local exercises that evening, as representing the authority now virtually continuing such work for the world at large.

Dr. Mailloux who it had been feared could not attend, then made a brief but forcible appeal for a permanent memorial, and voiced the sentiment of the audience in giving a mandate to the committee to proceed until that end had been accomplished.

On Monday, November 22, the Sheldon Memorial Committee met, reorganized and reelected Mr. T. C. Martin as chairman and Dr. Erich Hausmann as secretary. In view of the unanimous vote to raise funds for a Sheldon Foundation, Mr. Charles E. Potts, of the Committee and treasurer of the Polytechnic Institute, was elected as treasurer. Literature was also approved for launching an appeal to the public for funds and a letter was received from Mr. W. A. White of the Polytechnic Corporation, appoving heartily of the movement and contributing $1000. In the meantime it was voted to make a permanent record of the memorial meeting, letters of regret and appreciation, resolutions etc., and deposit it for preservation in the Institute archives in Brooklyn.

FEDERATED AMERICAN ENGINEERING SOCIETIES

ORGANIZATION MEETING OF AMERICAN ENGINEERING COUNCIL, WASHINGTON, D. C. NOVEMBER 18-20, 1920

The organization meeting of the American Engineering Council, in Washington, November 18-20, successfully and enthusiastically brought into effect the recommendations made by the Joint Conference Committee of the Development Committees of the four national Societies of Civil, Mining, Mechanical and Electrical Engineers in their report to these four societies, under date of September 17, 1919.

The various steps leading up to this organization have been referred to from month to month in this JOURNAL covering a period of more than two years.

The following is a complete list of the societies that have already joined the Federation, and the names of the official representatives of these societies upon American Engineering Council.

Member Societies and Representatives

Alabama Technical Association
- Paul Wright, Birmingham, Ala.

American Institute of Chemical Engineers
- Allerton S. Cushman, Washington, D. C.
- Harrison E. Howe (*alternate*), Washington.

American Institute of Electrical Engineers
- Calvert Townley (*chairman*), New York.
- Comfort A. Adams, Cambridge, Mass.
- A. W. Berresford, Milwaukee.
- H. W. Buck, New York.
- F. L. Hutchinson, New York.
- W. A. Layman, St. Louis.
- William McClellan, Philadelphia.
- L. F. Morehouse, New York.
- Lewis T. Robinson, Schenectady.
- Charles S. Ruffner, New York
- Charles F. Scott, New Haven, Conn.
- Lewis B. Stillwell, New York.
- John H. Finney, (*alternate*), Washington, D. C.
- G. A. Waters, (*alternate*), St. Louis, Mo.

American Institute of Mining and Metallurgical Engineers
- Herbert Hoover, Palo Alto, Calif.
- J. Parke Channing, New York.
- Arthur S. Dwight, New York.
- Edwin Ludlow, New York.
- Allen H. Rogers, Boston, Mass.
- Philip N. Moore, St. Louis.
- John V. W. Reynders, New York.
- Joseph W. Richards, Bethlehem, Pa.
- Percy A. Barbour (*alternate*), New York.

American Society of Agricultural Engineers, Ames, Iowa
- Samuel H. McCrory, Washington.

American Society of Mechanical Engineers
- L. P. Alford, (*chairman*), New York.
- Charles T. Main, Boston, Mass.
- Arthur M. Greene, Jr., Troy, N. Y.
- E. S. Carman, Cleveland, Ohio.
- Arthur L. Rice, Chicago, Ill.
- Dexter S. Kimball, Ithaca, N. Y.
- Paul Wright, Birmingham, Ala.
- W. A. Hanley, Indianapolis.
- William B Gregory, New Orleans.
- V. M. Palmer, Rochester, N. Y.
- H. P. Porter, Tulsa, Okla.
- Robert H. Fernald, Philadelphia.
- L. C. Nordmeyer, St. Louis.
- Fred J. Miller (*alternate*), Centre Bridge, Pa.
- Robert Sibley (*alternate*), San Francisco, Calif.
- Charles Whiting Baker (*alternate*), New York.

Associated Engineering Societies of St. Louis, Mo.
- William E Rolfe, St. Louis.

Detroit Engineering Society
- D. J. Sterrett, Detroit.

Engineering Association of Nashville
- C B. Howard, Nashville.

Engineering Society of Buffalo
- W. B. Powell, Buffalo, N. Y.

Grand Rapids Engineering Society
- Burritt A. Parks, Grand Rapids, Mich.

Kansas Engineering Society
- Lloyd B. Smith, Topeka, Kan.

Louisiana Engineering Society
- William B. Gregory, New Orleans, La.

Mohawk Valley Engineers' Club
- Byron E. White, Utica, N. Y.

Taylor Society, New York
- Morris L. Cooke, Philadelphia, Pa.

Technical Club of Dallas
- O. H. Koch, Dallas, Tex.

The Cleveland Engineering Society
- John F. Oberlin, Cleveland.

The Engineers' Club of Baltimore
- W. W. Varney, Baltimore.

The Society of Industrial Engineers, Chicago, Ill.
- L. W. Wallace, Baltimore, Md.
- F. S. Webner, (*alternate*), Washington.

Washington Society of Engineers
- E. C. Barnard, Washington.

York Engineering Society
- William J. Fisher, York, Pa.
- H. A. Delano (*alternate*), York, Pa.

The following is a list of the organizations which participated in the Washington meeting, but which have not yet officially become members of the Federation, together with the names of their delegates.

Participating Organizations and Delegates*

American Institute of Architects
- Percy C. Adams, Washington, D. C.

American Society of Heating and Ventilating Engineers
- Champlain L. Riley, New York, N. Y.

American Society for Testing Materials
- C. D. Young, Reading, Pa.
- C. L. Warwick, Philadelphia, Pa.

Engineering Society of Western Mass.
- Chas. L. Newcomb.

Florida Engineering Society
- L. R. McLain, St. Augustine, Fla.

Illuminating Engineering Society
- Walter C. Allen, Washington, D. C

Iowa Engineering Society
- John H. Dunlap, Iowa City, Iowa.

Joint Technical Council of San Francisco, Cal.
- Robt. Sibley, San Francisco.

National Fire Protection Association, Boston, Mass.
- Ira H. Woolson, New York, N. Y.
- D. Knickerbacker Boyd, Philadelphia, Pa.

Society of Automotive Engineers
- Howard E. Coffin, (*Chairman*), Detroit, Mich.
- David Beecroft, New York, N. Y.
- Coker F. Clarkson, New York, N. Y.
- H. M. Crane, New York, N. Y.
- C. F. Kettering, Dayton, Ohio.
- H. M. Swetland, New York, N. Y.

Society for the Promotion of Engineering Education
- F. L. Bishop, Pittsburgh, Pa

Temporary Organization

The opening session on Thursday morning, November 18, 1920, was called to order by Richard L. Humphrey, Chairman of the Joint Conference Committee, which had acted as the organizing

*These organizations are either considering or have given the matter of membership favorable consideration but have not taken final action.

committee of the meeting in accordance with the action of the preliminary organizing conference held in Washington in June 1920. Mr. Humphrey made a brief address reviewing the steps that had been taken toward organizing the Federation since last spring, including the preparation of a suggested program for this meeting.

Mr. Humphrey said in part, "You are embarking on a broad field of activity under the critical but hopeful eyes of the entire engineering and allied technical professions. It, therefore, behooves you to maintain the high ideals and add to the traditions of these professions. The unanimity of desire of the allied engineering and technical professions for a comprehensive organization that can speak for them in matters of public welfare, where technical training and engineering experience are involved, as well as in matters of common concern to these professions, culminated in the unanimous creation of The Federated American Engineering Societies and of its governing board, American Engineering Council—and has attracted a world-wide interest. Those who desire this comprehensive body are looking with confidence to the results of your labors. A great responsibility, therefore, rests upon you—that of justifying this confidence. The first step in realizing the dream of the engineering and allied technical professions for solidarity has been taken. The development of this solidarity is in the hands of the representatives of the Member Societies of The Federated American Engineering Societies. The profession is looking with intense interest to this meeting and is hopefully anticipating forward work. The confidence which the speaker felt and voiced in his opening remarks at the Organizing Conference concerning the success of that meeting he now feels in far greater measure for the success of The Federated American Engineering Societies in accomplishing the desired end of solidarity in the engineering and allied technical organizations, because of the great and growing enthusiasm for this organization; with no desire to repeat his previous address at the opening of the organizing Conference on June 3, the speaker wishes to emphasize that in his judgment the keynote of that meeting was the 'desire first to serve our country, and, second, to serve the societies and organizations of which we are the representatives.' And it would seem to the speaker from all the circumstances which have led up to the creation of this organization, that the keynote of whatever policy you may agree upon now should be 'Service.' Indeed, the organization by the preamble adopted at the Organizing Conference, at which it was created, is dedicated to the service of the City, State and Nation. In living up to this, you should carefully guard each act and each step in the progress of the organization, to the end that The Federated American Engineering Societies shall stand for the highest possible ideals and shall enrich the glorious traditions of the engineering and allied technical professions."

The temporary organization of the Council was then effected. Mr. Edwin S. Carman, of Cleveland, President-Elect of the American Society of Mechanical Engineers, was elected temporary Chairman; Mr. William E. Rolfe, of St. Louis, temporary Secretary.

Chairman Carman took the chair and the roll call of Societies and their delegates followed. All the societies listed on the program were represented. It was voted that participating organizations which were represented by delegates but which had not yet become members of the Federated Societies be given the privilege of the floor throughout this meeting of the American Engineering Council.

Temporary committees were appointed as follows:

Credentials. Messrs. O. H. Koch (Chairman), A F Ganier, S. H. McCrory, L. F. Morehouse, John J. Oberlin, B. A. Parks, Charles S. Ruffner.

Program. Messrs. Percy E. Barbour (Chairman), W. J. Fisher, W. B. Gregory, H. E. Howe, V. M. Palmer, W. W. Varney, G. A. Waters, P. Wright.

Constitution and By-Laws. Messrs. C. F. Scott (Chairman), R. H. Fernald, A. F. Ganier, C. T. Main, William McClellan, A. L. Rice, A. H. Rogers, W. E. Rolfe, B. E. White.

Nominations. Messrs. W. B. Powell (Chairman), L. P. Alford, E. C. Barnard, A. W. Berresford, W. B. Gregory, W. A. Hanley, D. S. Kimball, E. Ludlow, Wm. McClellan, W. E. Rolfe, L. B. Smith, L. B. Stillwell, L. W. Wallace.

Plan and Scope. Messrs. L. C. Nordmeyer (Chairman), H. Hoover, H. E. Howe, S. H. McCrory, J. F. Oberlin, V. M. Palmer, D. J. Sterrett, C. Townley, B. E. White.

Budget. Messrs. Calvert Townley, (Chairman), J. Parke Channing, A. M. Greene, W. B. Gregory, F. L. Hutchinson, O. H. Koch, B. E. Parks, Jos. W. Richards, D. J. Sterrett, W. W. Varney.

Resolutions. Messrs. F. S. Webner (Chairman), E. C. Barnard, J. H. Finney, P. N. Moore, L. B. Smith, P. Wright.

The representative named as Chairman of each committee was a temporary appointment to call the committee together; as soon as the committee convened it was to elect its own chairman. A motion was also passed to the effect that when a delegate or representative was absent and an alternate had been chosen, the alternate take the place of the representative or delegate or both on committees and in voting.

Location of Headquarters

The discussion on this topic was opened by Mr. Philip N. Moore, who favored Washington as the headquarters. Mr. Moore was followed by Mr. Calvert Townley, who did not advocate any particular place for headquarters but favored referring the decision of this important question to the Executive Board for consideration after all the essential facts bearing upon the matter were obtainable. Considerable discussion took place on this item, and a motion was finally made and seconded as follows:

> MOVED: That it is the sense of this meeting that the headquarters should be established in Washington.

The question was laid on the table for further debate until the afternoon. At that time the question was further discussed. Several amendments to the motion were suggested but did not carry, one of the amendments so lost being to the effect that the matter be referred to the Executive Board. On a rising vote of 29 affirmatives to 14 negatives, the above motion was adopted.

Employment Service

A statement regarding the Employment Service at present conducted under the auspices of the four Founder Societies, was made by Mr. F. L. Hutchinson, who briefly outlined the scope and extent of the work and presented a recent communication addressed to the Chairman of the Joint Conference Committee by Mr. Calvin W. Rice, Chairman of the Board of Direction of the Engineering Societies Service Bureau, containing recommendations regarding the funds that should be appropriated to continue the work advantageously during the coming year.

Mr. Hutchinson called attention to the fact that the Joint Finance Committee of the Founder Societies has adopted a recommendation recently to the effect that the employment activities be carried on after January 1, 1921, under the auspices of the American Engineering Council by a board consisting of the secretaries of all the societies represented in The Federated American Engineering Societies, and that these recommendations had been approved by the governing boards of the national societies of Mining, Mechanical and Electrical Engineers.

After some further discussion it was voted that the matter of conducting the Employment Service be referred to the Committee on Plan and Scope, which later reported favorably.

Committee on Credentials

This committee reported at the opening of the afternoon session on Thursday to the effect that the committee found that the printed list of representatives as printed on the preliminary

program was a complete list of the members of American Engineering Council and should be considered the official roll of the representatives on the Council. The committee then named certain alternates in addition to those named on the printed list and who had been appointed to attend this meeting in place of some of the official representatives who were absent.

It was voted to adopt the report of the Committee on Credentials, including acceptance of the credentials of the alternates named by the committee.

Committee on Program

The Committee on Program reported recommending that the tentative program as prepared by the Organizing Committee be approved as the program of this meeting, subject to such incidental revision as the presiding officer might deem desirable during the meeting.

This report was approved.

Engineering Council

Mr. J. Parke Channing, Chairman of Engineering Council, made a brief address relating to the activities of the Engineering Council, of which he had been Chairman during the past three years. (Most of these activities have been quite fully covered from month to month in the issues of the JOURNAL.)

Mr. Channing then said, "I would suggest that the new American Engineering Council follow in a general way the lines of Engineering Council based on its four years' experience. You will find that you will have to be most rigorous in determining what activities you may undertake and will have to turn down many suggestions which, though made in good faith, you will find are beyond the province of your Council. The broad principle which we have followed and which has been our motto is that 'Engineering Council is an organization of National Technical Societies of America, created to provide for consideration of matters of common concern to Engineers, as well as those of public welfare in which the profession is interested, in order that united action may be made possible.' Organized as you are with a broader support than Engineering Council, you will be able to make recommendations on State and local questions through local societies which are members of your body, by giving them information and instructing them on the broad principles which you support. You must be careful not to permit yourself to be used for movements which however good in themselves are not especially under the purview of engineers."

Mr. Alfred D. Flinn, Secretary of Engineering Council, Dr. D. S. Jacobus and Philip N. Moore also made brief statements relative to the activities of Engineering Council and including suggestions relative to the activities of the newly organized American Engineering Council.

Publicity

Mr. L. P. Alford called attention to the splendid cooperation of the technical press in giving publicity to the bulletins issued by the Joint Conference Committee containing information in regard to The Federated American Engineering Societies and American Engineering Council. He also called attention to the fact that the daily press was giving considerable publicity to engineering activities, and cited an instance where recently a single piece of engineering news was circulated to the extent of 2,500,000 copies of the papers of New York City.

Transportation

Mr. L. B. Stillwell, of New York, made a brief address on the broader features of transportation problems, including reference to the increasing use of motor truck transportation and the resulting effect upon the highways of the country.

Industrial Relations

At the opening session on Friday morning, November 19, 1920, Mr. L. W. Wallace of Baltimore, President of the Society of Industrial Engineers, made an address in which he emphasized the benefits, in industrial establishments, of the safety and welfare movements, medical departments and related service in these days of intensive and mass production. He made a plea for extension of the efforts to provide ample opportunity for the workmen to develop and become broader minded employees and citizens, fitted for advancement to the fullest possible extent.

Permanent Organization

The Committe on Nominations presented its report at the Friday morning session and recommended the election of the following officers:

President: (2 years)	Herbert Hoover, American Institute of Mining and Metallurgical Engineers
1st Vice-President: (2 years)	Calvert Townley, American Institute of Electrical Engineers
2nd Vice-President: (2 years)	William E. Rolfe, Associated Engineering Societies of St. Louis
3rd Vice-President: (1 year)	Dexter S. Kimball, American Society of of Mechanical Engineers
4th Vice-President: (1 year)	J. Parke Channing, American Institute of Mining and Metallurgical Engineers
Treasurer: (1 year)	L. W. Wallace, Society of Industrial Engineers

These officers were all unanimously elected. Vice-President Calvert Townley then took the chair, and the Vice-Presidents and Treasurer briefly expressed their appreciation of the honor of their election.

President Herbert Hoover was then escorted to the platform and in the brief address of acceptance expressed his strong conviction of the great field of usefulness of The Federated Body and The American Engineering Council, to the engineering profession and to the country.

Constitution and By-Laws

Professor Charles F. Scott presented a report of the Committee on Constitution and By-Laws, recommending that the Constitution and By-Laws which were tentatively approved at the preliminary conference in June 1920 be adopted, with a number of amendments.

After considerable discussion the meeting adjourned, and the same subject was continued at the afternoon session, when after further discussion, during which various amendments were suggested, the Constitution and By-Laws were adopted, including most of the amendments recommended by the committee. Some of these amendments were as follows:

> The name of the executive officer was changed from "Secretary" to "Executive Secretary."
>
> The provision in the tentative draft that no portion of the funds of The Federated American Engineering Societies should be "applied to the use of" local affiliations or State councils, was changed to read "no portion of such funds shall be appropriated for the operating expenses of local affiliations of State councils."
>
> The provision for holding the regular monthly meetings of the Executive Board was changed to provide for "regular meetings at least bi-monthly except during July and August" and also for a regular meeting to be held in connection with the meeting of the Council.
>
> The requirement that the contributions of member societies should be payable in advance in "semi-annual" payments, was changed to "quarterly" payments.

A few other amendments were adopted principally for the purpose of clarifying the meaning.

Plan and Scope

The report of the Committee on Plan and Scope was presented on Friday afternoon, and upon motion was accepted and referred to the Executive Board. The report follows:

The preamble to the Constitution lays down the cardinal principles that service to others is the keynote of the organization. To further this aim and to suggest concrete ways in which such services may be most effectively rendered, attention

is directed to certain general subjects upon which, among many others, such action may well be taken as may appear to the council or to the board to be most expedient.

Such services may take many different forms, and the extent to which it may be rendered will turn largely upon the question of financial ability to perform the service as well as upon the general question of the expediency or policy of entering into it.

One of the most fruitful and important fields of endeavor lies in the contact with governmental legislation, national, state and local, and rendering assistance in an advisory capacity, to the end that sound engineering principles may be adhered to. Assistance and advice to public bodies and officials on matters of a general engineering character and the suggestion or approval of competent engineering talent for a particular public service also forms an important object.

The fields of endeavor in which the Council and the Board may serve are of so widely varying a nature that it would be unwise to take any action which might unduly limit them in their activities. It should be a fundamental policy that subjects for consideration and action may be initiated by the executive Board itself as well as upon request or suggestion from outside sources, whether governmental or private.

The method of procedure of the original Engineering Council, whereby various subjects were handled through standing or special committees whose membership was composed of men best qualified to deal with specific subjects, regardless of whether they were members of the Council or not, is endorsed.

Among some of the topics which have heretofore engaged the attention of the Council and which illustrate the kind of activities in which this organization may well engage are:

1. To serve the public interest by investigation and advice to the public, and governmental and voluntary bodies, upon all local and national problems which involve industrial and economic question.
2. National Department of Public Works.
3. Conservation of natural resources, such as water, coal, oil, etc.
4. Maintenance of a cooperative attitude toward other national organizations, professional, industrial and commercial.
5. Technical education.
6. Transportation in its various forms, particularly highways.
7. Advice with and assistance to regional, state and local organization upon their request.
8. National Bureau of Economic Research.
9. Public Fire Protection.
10. Patents.
11. National Board of Jurisdictional Awards.
12. International affiliation of engineers.
13. State Organizations of local affiliations.
14. Uniform Licensing and Registration Laws.
15. Classification and Compensation of Engineers.
16. Employment service bureau.
17. Russian-American engineers committee.

The above list of suggested activities is illustrative only and is in no sense intended to limit the field of operation of the Executive Board.

Engineering Council's advice has already been sought and given upon the subject of Water Power and Water Conservation by the Federal Water Power Commission and by the State of Maine. From this beginning, it is fair to assume that the field for such service will constantly be enlarged until the organization becomes an invaluable aid in the formulation of broad public policies in which engineering is involved.

Every care should be exercised, however, to avoid any action partaking of political bias or partisanship and to keep the activities and pronouncements of the Federated American Engineering Societies within the pale of sound engineering, good judgment and upon the broad basis of a real and mutual cooperation.

Budget

The Committee on Budget, through Mr. Calvert Townley, Chairman, presented a report containing estimates of receipts and expenditures, based upon the facts obtainable at the time and a knowledge of the expenses of Engineering Council during the year 1920. Due to the fact that in addition to the societies already members of the Federated American Engineering Societies a number of others will probably become members within the next few months, the committee prepared both minimum and maximum estimates of receipts and expenses with totals as follows:

Estimated Income, Minimum, $59,000, Maximum, $80,000;
Estimated Expenses, Minimum, $56,500, Maximum, $93,500.

This tentative budget was submitted with a recommendation that it be referred for consideration to the Executive Board for such modifications as may be deemed desirable after further development of the plans for the coming year. The report was accepted and the recommendation adopted.

Executive Board

The plan of organization tentatively approved last June provided for an Executive Board of thirty members, charged with conducting the business of the federated organization under the direction of the Council, six of these to be the president, four vice-presidents, and treasurer elected by the Council, and twenty-four to be selected, a part by the national societies, and the remainder by the local, state, and regional organizations and affiliations according to districts—the number representing the national societies to bear as nearly as possible the same ratio to the number representing the local, state and regional organizations as the number of representatives of the national societies on the Council bears to the number of representatives of the local and regional organizations. Therefore, under this plan, the national and local organizations should select twenty-four members of the Executive Board.

It was voted, however, that only twenty members be elected at this time. The object of leaving four vacancies on the Executive Board was to allow societies which may become charter members in the near future to have an opportunity to be represented upon the Board. It was decided to elect at this time fourteen members from the national societies and six from the local organizations, one from each of six geographical districts which are specified below together with the names of the organizations within these districts that have already become members of the federation.

	Approximate Membership
District No. 1—New York and New England States	547
Buffalo Engineering Society	
Mohawk Valley Engineers Club	
District No. 2—Michigan, Wisconsin, Minnesota	704
Detroit Engineering Society	
Grand Rapids Engineering Society	
District No. 3—Ohio, Indiana, Illinois	1241
Cleveland Engineering Society	
District No. 4—New Jersey, Pennsylvania, Delaware, District of Columbia	850
York Engineering Society	
Baltimore Engineers Club	
Washington Society of Engineers	
District No. 5—Virginia, West Virginia, North and South Carolina, Alabama, Kentucky, Mississippi, Florida, Georgia, Louisiana, Texas	
Louisiana Engineering Society	
Technical Club of Dallas	
Alabama Technical Council	
Engineering Association of Nashville	
Florida Engineering Society	
District No. 6—North and South Dakota, Nebraska, Kansas, Oklahoma, Arkansas, Missouri, Iowa	836
Kansas Engineering Society	
Iowa Engineering Society	
Associated Engineers of St. Louis	

Territory west of the above has not been divided into districts.

At the Friday afternoon session the following elections as

members of the Executive Board were announced, in accordance with the above plan:

NATIONAL SOCIETIES
- American Institute of Chemical Engineers:
  - Harrison E. Howe, Washington, D. C.
- American Institute of Electrical Engineers:
  - H. W. Buck, New York
  - William McClellan, Philadelphia
  - Charles F. Scott, New Haven
  - Lewis B. Stillwell, New York
- American Institute of Mining and Metallurgical Engineers:
  - Arthur S. Dwight, New York
  - Edwin Ludlow, New York
  - Philip N. Moore, St. Louis
- American Society of Agricultural Engineers:
  - Samuel H. McCrory, Washington, D. C.
- American Society of Mechanical Engineers:
  - L. P. Alford, New York
  - Arthur M. Green, Jr., Troy, N.Y.
  - Edwin S. Carman, Cleveland
  - Fred J. Miller, Center Bridge, Pa.
- Taylor Society:
  - Morris L. Cooke, Philadelphia

LOCAL STATE AND REGIONAL ORGANIZATIONS
- District No 1: (To be selected later)
- District No. 2: (To be selected later)
- District No. 3: John F. Oberlin, The Cleveland Engineering Society
- District No. 4: William W. Varney, The Engineers Club of Baltimore
- District No. 5: O. H. Koch, Technical Club of Dallas, Texas
- District No. 6: Lloyd B. Smith, Kansas Engineering Society, Topeka, Kansas

Resolutions

Upon recommendation of the Committee on Resolutions it was voted to express to the four Founder Societies the obligation and appreciation of the Federated American Engineering Societies for the establishment of the Joint Conference Committee which carried forward the plan for the organization of the federation, including the present meeting; a resolution was adopted expressing appreciation of the wholehearted support given to the movement of the organization of the federation by the daily and technical press; also a resolution of thanks to the engineering societies of Washington for the many courtesies extended to the representatives attending this meeting.

A resolution was also adopted thanking the Chairman of the Joint Conference Committee of the Founder Societies for his able and untiring efforts over a long period of time toward the organization of this federation of engineering societies. Chairman Humphrey of the Joint Conference Committee briefly expressed his gratification at having been identified with the movement, and emphasized the fact that the keynote of the deliberations of the Council at this meeting has been "service."

The afternoon session closed with brief addresses by Professor Charles F. Scott and Mr. George G. Anderson, relating to the field of activities and the opportunities of the engineering profession for service in the solution of the great industrial, economic and social problems of the day.

Friday Evening Session

A large and enthusiastic audience attended the Friday evening session, at which President Hoover delivered an address on "Some Phases of Relationship of Engineering Societies to Public Service," which is published in full elsewhere in this issue. The latter part of the evening was devoted to an informal reception and smoker tendered by the engineering societies of Washington to the visitors. The occasion was exceedingly enjoyable to all present and afforded opportunity for renewal of old, and making of new, acquaintances.

EXECUTIVE BOARD MEETING

The orgnization meeting of the Executive Board of the Council was held at the New Willard Hotel on Saturday morning, November 20, Mr. William E. Rolfe, second Vice-President, presiding. Messrs. Calvert Townley and William E. Rolfe were elected Vice-Chairmen of the Executive Board. The following is a resume of the actions taken:

The following Committee was appointed to present to the Executive Board later a list of names of eligible persons for the office of Executive Secretary: Messrs. Wallace, Chairman, Alford, Moore, Oberlin, Scott, Townley and the President. Mr. Alford was elected temporary Executive Secretary, with headquarters in the offices of the American Society of Mechanical Engineers, New York.

The appointment of the following standing committees was referred to the President with power:

(a) Constitution and By-Laws
(b) Publicity and Publications
(c) Membership and Representation
(d) Finance
(e) Public Affairs

Headquarters to be opened in Washington as soon as possible; temporarily in connection with the Washington office of the present Engineering Council.

The preliminary budget prepared by the temporary Budget Committee and presented at the meeting of the Council on the previous day was referred to the Finance Committee of the Executive Board for consideration.

The proposed establishment of a National Department of Public Works was endorsed in the following resolution:

RESOLVED that this Board recognizes the great importance and value of the movement to establish a National Department of Public Works as inaugurated by Engineering Council and continued by the National Department of Public Works Association, and this Board declares itself n favor of continuing the efforts to that end.

The Patents Committee of the Engineering Council was authorized to act on behalf of the Federated American Engineering Societies in continuing its efforts toward the passage by Congress of legislation toward adequate support of the Patent office.

The Board endorsed the plan of President Hoover for investigation of industrial waste, and authorized him to organize a Committee for that purpose. This Committee will be the instrument through which the Council will deal with labor, chambers of commerce, and other agencies in the solution of the problems of industrial relations.

Questions relating to the payment of dues by different classes of membership were referred to the Committee on Membership and Representation.

The report of the Committee on Plan and Scope as published above was accepted.

The Board adjourned to meet again at the call of the President, not later than January 1921.

It may be interesting to review briefly the steps leading to the formation of the Federated American Engineering Societies, which may be said to have had their origin shortly after the armistice was signed in November 1918, at which time there was quite naturally a general tendency of organizations of all kinds to review their activities, with the object of ascertaining what changes in organization and methods were desirable.

The A. I. E. E. and many other national organizations appointed committees for this purpose. The Development Committee, which was the name given to the A. I. E. E. representatives charged with making this survey for their society, began its work by providing ample opportunity for the membership of the Institute to express views and make suggestions for the consideration of the Committee. This was done through publication of statements by the President of the Institute and the Chairman of the Development Committee in the Institute PROCEEDINGS. Every member of the Institute was requested to make suggestions, and all Sections of the Institute were invited and urged to hold special sessions for the purpose of discussing the activities of the Institute and what, if any changes, were desirable. More than half the Sections held such meetings and forwarded summaries of their discussions to the Develop-

ment Committee. Many individual members also contributed their views.

The final report of this Committee, voicing the views which had thus been expressed by the membership, contained, together with many other items, a recommendation to the effect that cooperation in matters of common interest to the engineering profession be studied through the Joint Conference Committee of the Development Committees of the four national societies of Civil, Mining, Mechanical and Electrical Engineers. The Development Committees of the other societies made similar recommendations, as a result of which a Joint Conference Committee representing the four national societies referred to was organized in 1919, which Joint Committee made recommendations in September 1919 culminating in the organization of the Federated Societies as an instrument through which the engineering profession may encourage the application of engineering principles to the solution of the broad industrial economic and social problems, many of which are briefly referred to above.

Summarizing the entire proceedings at the Washington meeting, the results are exceedingly gratifying, indicating a high degree of interest, and there is every indication that the activities of the American Engineering Council will be developed and extended to meet the generally expressed wishes of the membership of the various societies concerned, representing the engineering profession.

In its leading editorial of Saturday, November 20, the Washington Herald said:

"When the history of the year 1920 comes to be written by chroniclers and interpreters of its important events they will say that the formation in this city of the American Engineering Council of the Federated American Engineering Societies was epoch marking. Conceived during the war, born during a period of reconstruction, it has within it even as a child among institutions, a power that statesmen, politicians, taxpayers and plain folk must reckon on as henceforth important.

The persons who are affiliated with this newly constituted council are experts as compared with ordinary civilians or public officials. As human beings, taxpayers and democrats, they are weary of the unnecessary costs, the bureaucratic tyrannies and futilities and the nonrepresentative methods of carrying on public business. They learned their lesson during the war while aiding the government to function. That which they then learned they are bound all their fellow countrymen shall know. If the latter profit by the instructions and advice well and good. But as for the engineers they are out to fight to the bitter end to conserve national wealth, facilitate cheap and swift transportation of goods and passengers, pacify warring capital and labor, coordinate governmental machinery, and make the proved facts of applied science count for more with the average American citizen than the imaginative eloquence of the political orator or the subtly perverted instruction of the hired journalist."

SOME PHASES OF RELATIONSHIP OF ENGINEERING SOCIETIES TO PUBLIC SERVICE*

BY HERBERT HOOVER
President American Federated Engineering Societies

The Federation of Engineering Societies has been created for the sole purpose of public service. This initial meeting surely warrants some discussion of a few of the problems to which this organization, for expression of the engineering mind, can quite well give consideration.

One of the greatest of the problems before the country and, in fact, before the world, is that growing out of our industrial development. The enormous industrial expansion of the last fifty years has lifted the standard of living and comfort beyond any dream of our forefathers. Our economic system under which it has been accomplished has given stimulation to invention, to enterprise, to individual improvement of the highest order, yet it presents a series of human and social difficulties to the solution of which we are groping. The congestion of population is producing subnormal conditions of life. The vast repetitive operations are dulling the human mind. The intermittency of employment due to the bad coordination of industry, the great waves of unemployment in the ebb and flow of economic tides, produce infinite wastes and great suffering. Our business enterprises have become so large and complex that the old personal relationship between employer and worker has to a great extent disappeared. The aggregation of great wealth with its power of economic domination, presents social economic ills which we are constantly struggling to remedy.

I propose to traverse only a small fraction of these matters. I do not conceive that any man, or body of men, is capable of drafting in advance a plan that will solve these multiple difficulties and preserve the system which makes individual initiative possible. We have presented to us economic social patent medicines of one kind or another, and, in fact, the great panacea of Socialism is today in actual trial in its various forms. In Russia the attempt has been made to apply the most extreme form of complete Communism. The Russian experiment is bankrupt in production. The populations of our modern states have been built up to numbers dependent upon an intensity of production that can only be maintained by stimulation of individual effort through the impulse of self-interest, and a departure from this primary incentive to production has now been demonstrated to lead only to famine and flame and anarchy. We have even had a gigantic experiment imposed upon the United States by the war in the necessity to operate a vast merchant marine at the hands of the government, with a result that should offer little consolation to those who advocate even the mildest application of Socialism.

We have built up our civilization, both political, social and economic, on the foundation of individualism. We have found in the course of development of large industry upon this system that individual initiative can be destroyed by allowing the concentration of industry and service, and thus an economic domination of groups over the whole. We have therefore built up public agencies intended to preserve an equality of opportunity through control of possible economic domination. Our mass of regulation of public utilities and of many other types of industry aiming chiefly to prevent combinations in restraint of free enterprise, is a monument to our attempts to limit this economic domination—to give a square deal. This regulation is itself also proof of the abandonment of the unrestricted capitalism of Adam Smith. While our present system of individualism under controlled capitalism may not be perfect, the alternative offers nothing that warrants its abandonment. Our thought, therefore, needs to be directed to the improvement of this structure and not to its destruction.

A profound development of our economic system apart from control of capital and service during the last score of years has been the great growth and consolidation of voluntary local and national associations. These associations represent great eco-

*Address of Herbert Hoover before the Federated American Engineering Societies, November 19, 1920.

nomic groups of common purpose, and are quite apart from the great voluntary groups created solely for public service. We have the growth of great employers' associations, great farmers' associations, great merchants' associations, great bankers' associations, great labor associations—all economic groups striving by political agitation, propaganda and other measure to advance group interest. At times they come in sharp conflict with each other, and often enough charge each other with crimes against public interest. And to me one question of the successful development of our economic system rests upon whether we can turn the aspects of these great national associations towards coordination with each other in the solution of national economic problems, or whether they grow into groups for more violent conflict. The latter can spell breakdown to our entire national life.

This engineers' association stands somewhat apart among these economic groups in that it has no special economic interest for its members. Its only interest in the creation of a great national association is public service, to give voice to the thought of the engineers in these questions. And if the engineers, with their training in quantitative thought, with their intimate experience in industrial life, can be of service in bringing about cooperation between these great economic groups of special interests, they will have performed an extraordinary service. The engineers should be able to take an objective and detached point of view. They do not belong to the association of either employers or labor, of farmers, or merchants or bankers. Their calling in life is to offer expert service in constructive solution of problems, to the individuals in any of these groups. There is a wider vision of this expert service in giving the group service of engineers to group problems.

We have just passed through a period of unparalleled speculation, extravagance and waste. We shall now not only reap its inevitable harvest of unemployment and readjustment, but we shall feel the real effect of four years of world destruction, and from it economic and social problems will stand out in vivid disputation. One of the greatest conflicts rumbling up in the distance is that between the employer on one side and organized labor on the other. We hear a great deal from extremists on one side about the domination of the employer, and on the other about the domination of organized labor. Probably the tendency to domination exists among the extremists on both sides. One of the most perplexing difficulties in all discussion and action in these problems is to eliminate this same extremist. There are certain areas of conflict of interest, but there is between these groups a far greater area of common interest, and if we can find measures by which, through coöperation, the field of common interest could be organized, then the area of conflict could be in the largest degree eliminated.

In this connection the employer sometimes overlooks a fundamental fact in connection with organized labor in the United States. This is that the vast majority of its membership and of its direction are individualists in their attitude of mind and in their social outlook; that the expansion of socialist doctrines finds its most fertile area in the ignorance of many workers, and yet the labor organizations, as they stand today, are the greatest bulwark against socialism. On the other hand, some labor leaders overlook the fact that if we are to maintain our high standards of living, our productivity, it can only be in a society in which we maintain the utmost possible initiative on the part of the employer; and further, that in the long run we can only expand the standard of living by the steady increase of production and the creation of more goods for division over the same numbers.

The American Federation of Labor has publicly stated that it desires the support of the engineering skill of the United States in the development of methods for increasing production, and I believe it is the duty of our body to undertake a constructive consideration of these problems and to give assistance not only to the Federation of Labor but also to the other great economic organizations interested in this problem, such as the Employers' Association and the Chambers of Commerce.

It is primary to mention the three-phase waste in production; first, from intermittent employment, second from unemployment that arises in shifting of industrial currents, and third from strikes and lockouts. Beyond this elimination of waste there is another field of progress in the adoption of measures for positive increase in production.

In the elimination of the great waste and misery of intermittent employment and unemployment, we need at once coordination in economic groups. For example, our engineers have pointed out time and again to the bituminous coal industry where the bad economic functioning of that industry results in an average of but 180 days' employment per annum, where a great measure of solution could be had if a basis of cooperation could be found between the coal operators, the coal miners, the railways and the great consumers. The combined result would be a higher standard of living to the employees, a reduced risk to the operator, a fundamental expansion of economic life by cheaper fuel. With our necessary legislation against combination and the lack of any organizing force to bring about this cooperation, the industry is helpless unless we can develop some method of governmental interest, not in governmental ownership, but in stimulation of cooperation in better organization.

In help against the misery in the great field of seasonal and other unemployment, we indeed need an expansion and better organization of our local and federal labor exchanges. We have a vast amount of industry, seasonal in character, which must shift its labor complement to other industries. The individual worker is helpless to find the contacts necessary to make this shift unless the machinery for this purpose is provided for him.

In the questions of industrial conflict resulting in lockouts and strikes, one mitigating measure has been agreed upon in principle by all sections of the community. This is collective bargaining, by which, whenever possible, the parties should settle their difficulties before they start a fight.

It is founded not only on the sense of prevention but on the human right to consolidate the worker in a proper balanced position to uphold his rights against the consolidation of capital. This measure, advocated for years by organized labor, was agreed to by the employers' group in the First Industrial Conference, It has been supported on the platform of both political parties. The point where the universal application of collective bargaining has broken down is in the method of its execution. The conflict arises almost wholly over the question of representation and question of enforcement. The employer in some industries denies the right of men other than his own employees to conduct the negotiations. Labor organizations demand that, as such negotiations require skill, experience and bargaining freedom, they are of more then local application and that thus they can only protect the body of workers by presenting the case on their behalf by skilled negotiators.

The Second Industrial Conference, of which I was a member, proposed a solution to this point by the provision that where there was a conflict over representation, the determination should be left to a third and independent party. It also proposed that each party should have the right to summon skill and experience to its assistance. It further proposed that where one of the parties at dispute refuses to enter upon collective bargaining, the entire question should be referred to an independent tribunal for investigation as to the right and wrong of the whole dispute—but only for investigation and report. That conference, embracing both a great employer and a most distinguished representative of organized labor, was completely convinced that the illumination of the public mind as to the rights and wrongs of these contentions would in itself make for material progress in their solution, and that in public education and the condemnation of public opinion of wrong-doing lay the root to real progress. No group should be afraid of authori-

tative publicity in these matters, and I believe it would greatly advance an understanding of the cause of labor. The Conference did not believe that industrial contention could be cured by compulsory arbitration or any other form of governmental repression which must in the end use the jails for enforcement. The principles formulated by that conference should have your consideration.

There are questions in connection with this entire problem of employer and employees relationship, both in its aspects of increased production and in its aspects of wasteful unemployment, that deserve most careful study by our engineers. There lies at the heart of all these questions the great human conception that this is a community working for the benefit of its human members, not for the benefit of its machines or to aggrandise individuals; that if we would build up character and abilities and standard of living in our people, we must have regard to their leisure for citizenship, for recreation and for family life. These considerations, together with protection against strain, must be the fundamentals of determination of hours of labor. These factors being first protected, the maximum production of the country should become the dominating purpose. The precise hours of labor should and will vary with the varying conditions of trades and establishments, but the proper determination of hours, based upon these factors, is an immediate field demanding attention of engineers. There is no greater economic fallacy than the doctrine that the decrease of hours below these primary considerations makes for employment, of greater numbers, and it is an equal certainty that the 84-hour week of some employments transgresses these fundamentals to a point of inhumanity.

There is a broad question bearing upon stimulation of self-interest and thus increase in production that revolves around the method of wage payment. I need not review to you the advantages, difficulties and weaknesses of bonus, piece work, profit or saving sharing plans that are in use as a remedy for the deadening results of the same wage payment to good and bad skill alike. The suggestion I wish to put for your consideration is the possible use of another device in encouragement of individual interest and effort by creating two or three levels of wage in agreements for each trade, the position of each man in such scale to be based upon comparative skill and character. This plan should be developed upon the principle of graded extra compensation, for added skill and performance, above an agreed basic wage. In order to give confidence, the classification under such scales must be passed upon by representatives of the workers in such shop or department. This plan is now being successfully experimented with.

We must take account of the tendencies of our present repetitive industries to eliminate the creative instinct in its workers, to narrow their field of craftmanship, to discard entirely the contribution to industry that could be had from their minds as well as from their hands. Indeed, if we are to secure the development of our people, we cannot permit the dulling of these sensibilities. Indeed, we cannot accomplish increased prodution without their stimulation. Here again we cannot make an advance unless we can secure cooperation between the employer and the employee. In large industry this mutuality of interest that existed in small units cannot be restored without definite organization.

There has been a great increase in shop committees as a method of such organization. Where they have been elected by free and secret ballot among the workers, where they are dominated by a genius desire on both sides for mutual cooperation in the shop, they have resulted in great good. One of the most important phases of that good has been the tendency to turn the aspect of some foremen from that of slave-driving to leadership. And a great good has been possible by the encouragement of men to creative effort, in the stimulation of their minds as well as their hands to the solution of these problems. It makes for pride of craftmanship and is a real effort o offer them an opportunity of self-expression. Organized labor has opposed some forms of these committees because of the fear that they may break down trade organization covering the area of many different shops. There is economic reason for this fear in certain cases, deeper than appears upon the surface. One of the greatest accomplishments of organized labor has been the protection of the workers from the unfair employer, and it is worth the employer's notice that this is at the same time the protection of the fair employer from the unfair competition of the sweat shop. Again I believe the engineers could assist in the erection of a bridge of cooperation if organized labor, which has already made a beginning, would extend more widely its adoption of the principles of a shop committee settling its problems of wage and conditions of labor in general agreement and applying its energies through shop committee organization to development of production as well as to the correction of incidental grievance. There would be little outcry against the closed shop if it were closed in order to secure unity of purpose in constructive increase of production by offering to the employer the full value of the worker's mind and effort as well as his hands.

There is an immediate problem in increased production that is too often overlooked by the theorist. While it is easy to state that increased production will decrease cost and by providing a greater demand for goods secure increased consumption and ultimate greater employment, yet the early stages of this process do result in unemployment and great misery. It takes a variable period of time to create the increased area of consumption of cheapened commodities, and in the meantime, when this is translated to the individual worker he sees his particular mate thrown out of employment. We accomplish these results over long periods of time, but if we would secure cooperation to accomplish them rapidly we must take account of this unemployment and we must say to the community that if it is to benefit by the cheapening costs and thus the increased standard of living, or alternatively if the employer is to take the benefits, the entire burden should not be thrust upon the individual who now alone suffers from industrial changes. Nor can this be accomplished except by cooperation between groups. In fact, the whole problem of unemployment needs earnest consideration.

In summary, the main point that I wish to make is this: that there is a great area of common interest between the employer and the employees through the reduction of the great waste of voluntary and involuntary unemployment and in the increase of production. If we are to secure increased production and an increased standard of living, we must keep awake interest in creation, in craftsmanship and the contribution of the worker's *intelligence to management*.

Battle and destruction are a poor solution to these problems. The growing strength of national organizations on both sides should not and must not be contemplated as an alignment for battle. Battle quickly loses its rules of sportsmanship and adopts the rules of barbarism. These organizations—if our society is to go forward instead of backward—should be considered as the fortunate development of influential groups through which skill and mutual consideration can be assembled for cooperation to the solution of these questions. If we could secure this cooperation throughout all our economic groups, we should have provided a new economic system, based neither on the capitalism of Adam Smith nor upon the Socialism of Karl Marx. We should have provided a third alternative that preserves individual initiative, that stimulates it through protection from domination. We should have given a priceless gift to the Twentieth Century.

I am not one of these who anticipates the solution of these things in a day. Durable human progress has not been founded on long strides. But in your position as a party of the third part to many of these conflicting economic groups, with your lifelong training in quantitive thought, with your sole mental aspect of construction, you, the engineers, should be able to make contribution of those safe steps that make for real progress.

NATIONAL RESEARCH COUNCIL

A RESEARCH INFORMATION BUREAU

The National Research Council has established a Research Information Service as a general clearing-house and information bureau for scientific and industrial research. This "Service" on request supplies information concerning research problems, progress, laboratories, equipment, methods, publications, personnel, funds, etc.

Ordinarily inquiries are answered without charge. When this is impossible because of unusual difficulty in securing information, the inquirer is notified and supplied with an estimate of cost.

Much of the information assembled by this bureau is published promptly in the "Bulletin" or the "Reprint and Circular Series" of the National Research Council, but the purpose is to maintain complete up-to-date files in the general office of the Council.

Requests for information should be addressed, Research Information Service, National Research Council. 1701 Massachusetts Avenue, Washgington, D. C.

A CALL TO INSTITUTE MEMBERSHIP TO ASSIST IN PATENT LEGISLATION

As the Nolan Patent Office Bill (H. R. 11,984) will be brought before the Conference Committee of the House and Senate probably about the middle of December, and as the bill has been so altered by the Senate Committee as to be rendered almost worse than useless as a remedy for the present Patent Office troubles, an appeal is again made to the engineering profession to exert all possible influence towards its passage in original form, In this connection your Board of Directors at their meeting of November 12, 1920 adopted the following resolution:

RESOLVED that the Board of Directors of the American Institute of Electrical Engineers hereby endorses the resolutions adopted by Engineering Council at its meeting in Chicago, relative to the desirability of obtaining adequate legislation in Congress for the support of the Patent Office, and directs that the matter be brought to the attention of the members of the Institute through publication in our monthly JOURNAL and recommends that individual members communicate with their representatives and senators in Congress urging prompt action.

The appeal for action as issued by Engineering Council, containing detailed information follows:

An Appeal to the Members of the American Institute of Electrical Engineers on behalf of the Nolan Patent Office Bill H. R. 11,984

The members of the Institute will doubtless remember that they, in cooperation with the other engineering societies represented in Engineering Council, together with other scientific and industrial organizations, have been giving support to an effort to relieve the present desperate condition of the United States Patent Office by passing Nolan Patent Office Bill H. R. 11.984.

The purpose of this bill is to increase the examining and clerical forces of the Patent Office and to raise their salaries so as to give that office a sufficient force and at salaries that will attract and hold competent men to enable it to make its examinations with that reasonable promptness which is necessary to make it worth while applying for them and with such thoroughness as to reduce the percentage of errors to as low a limit as sufficient time for the work and proper qualifications can possibly effect.

Engineering Council appointed its Patent Committee for the purpose of aiding the Nolan bill and urged the membership of the constitutent societies to communicate with the Patent Committees of the House of Representatives and the Senate and with the Representatives and Senators from the districts and states of the respective members on behalf of the said bill. The influence thus exerted, and that of other organizations, was so powerful that, at a hearing before the Rules Committee of the House of Representatives, which was largely attended by officers of members of Engineering Council and of the said societies and organizations, the Nolan bill was ordered made special and the House of Representatives promptly passed it without amendment by a very large majority.

A similar hearing on the bill was held by the Patent Committee of the Senate, but, in order to remove the objection to unanimous consent to a special hearing by the Senate, before adjournment of the session, the Patent Committee of the Senate consented to amendments so seriously reducing the force and salaries of the bill as passed by the House of Representatives as to reduce the examining and clerical forces below the numbers now actually employed in the Patent Office. The increases of the salaries provided in the bill were also cut down to where they are seriously inadequate to attract or hold a sufficient number of qualified men to enable the Patent Office to do its work. The steady exodus of examiners from the Patent Office, which has been going on for some time, has not been stayed at all by the passsage of the bill by the Senate.

The bill was referred by the Senate to a Conference Committee of which the Senate members are:

Senator Geo. W. Norris, of Nebraska,
Senator Geo. B. Brandegee, of Connecticut, and
Senator William F. Kirby, of Arkansas.

The members of the Conference Committee for the House of Representatives have not been appointed, but Hon. John I. Nolan, of California, is certain to be one.

Engineering Council regarding the matter as of grave importance unanimously passed the following resolutions on October 21st, 1920:

Resolution of Engineering Council Concerning the Nolan Patent Office Bill H. R. 11,984.

WHEREAS, the United States Patent Office is vitally important to our industries, to induce the production of scientific and technical improvements and to enable our industries to keep abreast of those other countries; and

WHEREAS, the volume of work of the Patent Office for many years has increased much more rapidly than its examining and clerical forces have been increased, and the work in the past fiscal year has increased thirty-six per cent above the work of the previous year; and

WHEREAS, the salaries of examiners, except for a war bonus, have only been increased ten per cent in seventy years and are so low that resignations of examiners are constantly occurring in a steady stream, averaging twenty-five per cent per annum, and resulting in such frequent changes that much inefficiency unavoidably results therefrom, even where examiners are qualified for the work, and many men are necessarily employed as examiners who cannot pass the examination required to qualify for their positions; and the salaries of the clerical forces are considerably below the average of salaries for corresponding work in the governmental departments generally; and

WHEREAS, as a result of such situation, the Patent Office is at such a great disadvantage that it unavoidably grants an undue proportion of defective patents, resulting in heavy losses both to the inventors and the public, due to useless development and unnecessary litigation, and the Patent Office is so far behind in its work that the value of many transactions with it is greatly reduced and in some instances destroyed by delay; and

WHEREAS, as a partial remedy for such situation Nolan Bill H. R. 11,984 was introduced into Congress providing for an increase in the examining corps of the Patent Office of but five and eight-tenths per cent and an increase in the clerical force of but three and nine-tenths per cent and providing increases in salary for the position of primary examiners from $2700 to $3900 and of assistant examiners in proportion, and providing increases in the salaries of the clerical force only to bring them up approximately to the average corresponding salaries of other Governmental Departments and Bureaus, and as the cost of the increased salaries and force of the said Nolan Bill was more than met by an increase in the fees for patents provided therein; and

WHEREAS, the United States Senate so amended the said Nolan Bill that instead of increasing it decreases the examining corps by fifteen and seven-tenths per cent and reduces the clerical force by about one per cent below the present insufficient numbers of said examining corps and clerical force actually employed in the Patent Office, as well as reduces the salaries, both of the examining and the clerical forces, so that the total present payroll is reduced five and nine-tenths per cent, notwithstanding that the increase in fees for patents which were made to provide funds for the increased force and salaries were retained in the bill; and

WHEREAS, in the opinion of Engineering Council, the general effect of the changes in force and salaries made by the Senate would amount to a catastrophe for the Patent Office; and

WHEREAS, the salary of $3900, provided in the bill as it passed the House of Representatives, is low for the position of Principal Examiner when compared with the salaries paid by private corporations and employers for engineers having a similar grade of responsibilites and requirements—that

is, engineers required to make and assume responsibility for final decisions in important matters and to have highly technical knowledge—especially as such examiners must have both legal and technical knowledge and notwithstanding allowance for the fact that Governmental salaries are not as high as those paid by private interests; and the salaries for other grades of examiners are low in proportion;

NOW, THEREFORE, BE IT RESOLVED: That Engineering Council, representing 45,000 engineers, regards it of large importance that the numbers of the examining and clerical forces for the Patent Office and the salaries therefor in Nolan Patent Bill H. R. 11,984 be restored to those in the bill as it passed the House of Representatives; that the bill be freed from any riders, such as Section 9 thereof, which may delay or jeopardize the passage thereof, and that the bill be made a law at the earliest possible moment.

ENGINEERING COUNCIL, having on the 21st day of October, 1920, passed a resolution urging the restoration to their original values of the figures for the examining and clerical forces of the Patent Office and the salaries therefor in the Nolan Patent Office Bill H. R. 11,984, recommends that the constitutent engineering societies which it represents request their memberships to communicate with their Representatives and Senators in Congress, urging action in accordance with the said resolutions.

As the Patent Office is steadily losing more and more of its competent men and is rapidly getting farther and farther behind in its work, and as to get much farther behind would mean for it practically to cease to function, and as the bill, as amended by the Senate, is wholly inadequate to accomplish its purpose and would be worse than useless, every effort should be made to induce Congress to restore the figures of the bill to their values as passed by the House of Representatives.

The Conference Committee will probably take the bill up for consideration the middle or latter part of December. Each member of the Society is therefore most earnestly requested to write or telegraph to the member of Congress from his District to the Senators from his State and to the members of the Conference Comittee urging that the figures of the Nolan Patent Office Bill H. R. 11,984 be restored to the values which passed the House of Representatives.

It would also be well to urge that the bill be freed from any riders not related thereto, so that its early enactment will not be hindered by opposition to such riders.

The fact that letters may have already been written Senators and Representatives at an earlier stage in the passage of this bill will not serve the present emergency, because the question now is not merely the passage of the bill, but the restoration of the figures which have been so seriously cut down by the Senate.

The names of the senators and representatives can be obtained from the World Almanac, or similar publications, and from postmasters.

In connection with this bill, engineers as a class for the first time, have exerted a powerful influence in a public matter, and they should see that their work is brought to a successful conclusion.

Yours very truly

J. Parke Channing
Chairman

Committee on Patents
Edwin J. Prindle, Chairman
J. Parke Channing, Secretary
Charles A. Terry, of A. I. E. E.
Frank N. Waterman of A. I. E. E.

ENGINEERING COUNCIL

Headquarters: 29 West 39th Street, New York

Organized by several national engineering societies, including the Institute, to represent their membership in matters of common interest, especially relationships of engineers to the public and to governments. Council is one result of a wide movement to enlarge the activities of engineers for patriotic, social and personal welfare.

NOTES OF INTEREST FROM REPORT OF NATIONAL SERVICE DEPARTMENT

For the first time since the establishment of the Washington office of Council the Congress has been in a long period of recess. A good opportunity has therefore been afforded to determine whether the Washington office is in large degree a legislative agent for engineers or whether its functions are, for the major part, of a more permanent and continuing nature. The writer is pleased to report that those engaged in the work are not sensible of any diminution in its amount since the Congrees adjourned. To the writer this is conclusive evidence that the opportunities for service through the Washington office of Council are always greater than the capacity of the office.

National Service. Requests for information and assistance received from members of the profession decreased slightly in number during July and August, but during September and the expired portion of October have exceeded all previous experience. It is of interest to note that a large proportion of these requests came from the technical schools and colleges. The subjects cover past legislation, engineering standards, selective employment and management, indictment of coal profiteers, and the procurement of public documents on many subjects.

Engineer on the Advisory Board to the Post Office Commission. It is gratifying to report that the efforts of Council to secure this appointment have met with success. Dean M. E. Cooley, a former member of Council, now occupies the position.

U. S. Board of Surveys and Maps. The success of Council's efforts to secure the creation of this Board is of record. Since Council's last meeting the organization of outside cooperating agencies has been completed and the entire program of coordination of the Government's mapping effort is now in operation.

Report of Board of Review of War Construction. At a previous meeting of Council a resolution was passed urging the printing of the report of the Board of Review by reason of its value and usefulness as an engineering document. At that time all prospect that this report would be printed had practically disappeared. It is therefore of interest to note that the report was finally printed and has received as wide distribution as the size of the edition would permit.

Federal Power Commission. When the Federal Water Power Act became a law it was the general supposition that $100,000 appropriated by the Bill for the expenses of the administration would be available. Under a decision of the Comptroller of the Treasury the only money available is the sum of $5000 to cover the salary of the Executive Secretary. All work done has been by persons assigned temporarily by the Departments of War, Interior and Agriculture. Applications for permits now number 66, with an aggregate capacity in excess of 2,000,000 horse power. The Power Commission is unable to perform its functions in anything like a satisfactory way.

Topographic Mapping. An estimate of $600,000 for topographic mapping during the next fiscal year has recently been approved. Council last year passed a resolution favorable to an appropriation of $500,000. The amount made available by Congress was $375,000. The additional $100,000 requested for the present year is to make possible achieving in some measure the program that would have been made possible had the estimate of last year been approved.

Appropriations for Research Work. Large increases in estimates will be submitted by the various Bureaus, especially by the Bureau of Standards, so that they can increase activities in their fields and make their work more effective along technical and industrial lines.

National Department of Public Works. Resumption of legislative effort in support of a National Department of Public Works will take place prior to the next meeting of Council. It therefore appears advisable to make a rather complete report on the progress of that movement.

Country-Wide Movement for Government Reorganization. The fundamental arguments for a department of public works apply with equal force to the entire Government organization. There has grown in a short space of time a country-wide movement for Government reorganization. It is a part of the platform of one of the great political parties. It was frequently mentioned and advocated in the speeches of the several candidates, and was the text for many a campaign speech and newspaper or magazine article. The National Education Association, the Women Voter's League and the Federation of Women's Clubs, are supporting a proposed department of education. The American Public Health Association and other organizations in the realm of sanitation and preventative medicine are supporting a department of health. Certain welfare organizations are advocating a department of public welfare; there is also a movement for a department of aeronautics; and an old movement for a department of mines still exists. The National Budget Committee, having practically completed its labors in behalf of a budget system of Federal finance, is actively turning its attention to the entire field of Federal reorganization.

The National Budget Committee, the Public Works Department Association, and the National Education Association are participating in the activities of what is known as the National Committee for Governmental Economy, the purpose of which is to make and report upon a complete study for governmental reorganization. The report is practically completed.

In all of these organizations, with possibly one exception, the creation of a department of public works is an accepted doctrine. Opposition exists in some of the organizations to the purposes of some others, but all unite in favoring a public works program, and the most favorable feature of this is the general agreement that the department of public works should be created not through the creation of an additional Cabinet office but by a readjustment of the agencies already existing. It is the other new departments therefore that will have to carry the heavy legislative burden of overcoming the opposition to enlargement of the Cabinet.

Possibility of Amalgamating all Reorganization. Early in October there was a meeting in New York City, attended by Mr. John T. Pratt, head of the National Budget Committee; Mr. Herbert Hoover; Mr. Henry L. Stimpson, former Secretary of War; Mr. Paul Warburg; Major C. T. Chenery, and the writer (M. O. Leighton), at which matters of Government reorganization were discussed, and particularly the need for and the possibility of amalgamating all reorganization efforts under a commonly accepted and supported program. It was brought out that if many organizations conduct campaigns separately, each for its own particular project, the confusion created in Congress will probably result in no legislation. It was therefore decided to call a meeting of delegates from the several organizations advocating reform in the Government departments, to organize a Federal Reorganization Council, which would be the common body through which an accepted program would be carried forward.

The aforesaid meeting of such delegates was held in New York on October 14th, at which time the nearly completed report of the National Committee on Governmental Economy was presented. That program provided for a general rearrangement of Government activities along functional lines, including the creation of a department of public works by a reorganization of the present Interior Department, and an additional department to be called the Department of Education and Health, into which would be drawn such welfare activities as war risk insurance, vocation and rehabilitation, pensions, etc. The meeting for final organization was scheduled to take place about November 15th. The prospective field of such a council is not limited to the mere reorganization of Federal activities. It should become the authoritative unofficial body to engage in the work which will eventually lead to a distinct separation of the political features of our Government system from the conduct of departmental business.

There is also being discussed the consolidation of the Public Works Association with the National Budget Committee. This move appears to be wise from the standpoint of efficiency and economy. Inasmuch as the Budget Committee has adopted the public works principle the two organizations if separately sustained will largely duplicate each other's efforts.

To summarize as to the prospects for a department of public works: It is the writer's belief that the principle is thoroughly settled in the minds of the public and of a majority of the members of Congress.

PERSONAL MENTION

C. D. Young succeeds Albert Ladd Colby, resigned, as representative of the American Society for Testing Materials on Engineering Council.

Major James R. Werth has been appointed Commercial Service Manager of the West Penn Power Company with offices at West Penn Building, 14 Wood Street, Pittsburgh, Pa.

S. N. Dalal, who was assistant superintendent in the electrical workshop, College of Engineering, at Poona, India, has left that post to become superintendent of stores and workshop, Royal Institute of Science, Bombay.

G. L. Hoadley, formerly head of the Department of Electricity, American School of Correspondence, Chicago, has accepted the position of associate professor of Electrical Engineering at the Washington State College, Pullman, Washington.

Charles E. Burgoon has resigned from the position of staff assistant, in charge of appraisals, to the Director of Supply & Sales, United States Shipping Board Emergency Fleet Corporation, Washington D. C., to accept the position of Property and Records Engineer with the Cuba Cane Sugar Corporation, Havana, Cuba.

R. F. Hayward, formerly general manager of the Western Canada Power Company, Ltd., Vancouver, B. C., has relinquished this office to become general manager of the Chilian Electric Tramway & Light Company, Ltd., Santiago, Chile. He left the United States in November to take up his new duties. Mr. Hayward expects still to be able to keep up his interest in A. I. E. E. affairs, though at such a great distance.

H. H. Barnes, Jr., district engineer of the General Electric Company in New York, has been appointed assistant district manager. Mr. Barnes is a very active member of the Institute, acting as chairman of the Law Committee and the Special Committee of Geographical Division and Election Procedure. He is also a member of the Edison Medal Committee and is on the Board of Trustees of the United Engineering Society.

L. W. Chubb, of the Westinghouse Electric & Manufacturing Company, has been appointed manager of the company's new Radio Engineering Department. Mr. Chubb is known to many members of the Institute by his interest in its activities,

having served for a number of years on various committees; at present he is a member of the Meetings and Papers Committee Standards Committee, Electrophysics Committee, and the United States Committee of the International Electrotechnical Commission. He ha sbeen with the Westinghouse company for the past fifteen years, in both research and practical work.

Dr. E. F. Northrup, who resigned his professorship at Princeton University to devote his attention to the newly-formed Ajax Electrothermic Corporation, of Trenton, N. J., is now vice-president and technical advisor of that company. The company as incorporated is controlled by the Ajax Metal Company of Philadelphia, from which it takes over the Northrup furnace patents. It takes over also the manufacture and sale of the Ajax-Northrup high-frequency induction furnace from the Pyroelectric Instrument Company of Trenton, of which Dr. Northrup was formerly president.

E. C. Morse, Director of Sales, War Department, Washington, D. C., has tendered his resignation to the War Department, effective December 31, or earlier. Mr. Morse went to Washington during the early days of the war as representative of the Westinghouse Electric & Manufacturing Company, but was soon induced to enter the Government service in the Purchase Branch of the Construction Division of the Army. He remained with that organization until the Office of the Director of Sales was organized for the purpose of disposing of surplus Army supplies, when he was made Assistant Director of Sales in January, 1919, later becoming Director of Sales. He will return to civil life, but has not yet decided upon the line of work he will follow.

OBITUARY

Oscar Hansen, an Associate of the Institute, died on October 31, 1920. Mr. Hansen was born in Kenosha, Wisconsin, May 15, 1872; he received his early education in Kenosha and later finished the course in electrical engineering at the University of Wisconsin. He had been employed at various times by the Western Electric Company, Gibbs Brothers of Milwaukee, Wis., the Chicago Telephone Company, The Sanitary District of Chicago, and at the time of his death was an electrical engineer for the City of Chicago.

Angus Kenneth Miller, Engineer of Substation Construction with the New York Municipal Railway Corporation, Brooklyn, N. Y., died November 1, 1920, at Saranac Lake, N. Y. Born at Bridgsburg, Canada, December 1, 1879, Mr. Miller received his technical education at McGill University, Montreal. He had been with the Westinghouse Electric & Manufacturing Company for about five years before entering the employment of the Brooklyn Rapid Transit Company. He became an Associate of the A. I. E. E. in 1907.

Henry Hovelson, an Associate of the Institute, died on May 28, 1920, of appendicitis, at St. Barnabas Hospital, Minneapolis. Mr. Hovelson was born in Minneapolis, February 1, 1881. He completed the electrical engineering course at the University of Minnesota in 1908, after which he was engaged with various engineering concerns in electrical construction and design. At the time of his death he was connected with the Marshall-Wells Company, of Duluth, as Engineer and Estimator. He became ill in Duluth the latter part of April, and left then for Minneapolis, which had been his home the greater part of his life. Mr. Hovelson joined the Insttute in 1916.

Charles Ernest Acker died at his home at Ossining, N. Y., on October 18, 1920. Mr. Acker, manufacturer and inventor, had received the Elliot-Cresson gold medal of the Franklin Institute and several other medals for his development of the first electrolytic process for the manufacture of caustic soda by the electrolysis of molten salt, known as the Acker process. He was born at Bourbon, Ind., March 19, 1868, and was educated at Wabash College and Cornell University. From 1888 to 1893 he was engaged in electrical engineering work in Chicago, but after that time turned his attention to chemistry and electrochemistry. He built the works of the Acker Process Company, at Niagara Falls, originated processes for the manufacture of tetrachloride of tin and carbon tetrachloride and was the first to manufacture carbon tetrachloride in America. Mr. Acker was a director of the American Electrochemical Society; a member of the Society of Arts, London; Faraday Society, London; American Chemical Society; Society of Chemical Industry; Chemists' Club; and the Institute, which he joined as Associate in 1903.

ENGINEERING SOCIETIES LIBRARY

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

CATALOGING OF THE LIBRARY

The Engineering Societies Library of today has for its ancestors four separate libraries which began at different periods, were developed in different ways and with varying ideals, and had not attained the same degrees of development when they were combined. The methods of classifying the books and of cataloging them in use in the separate libraries were so dissimilar that a revision of all this work was essential if members were to use the collection conveniently, and with any assurance that all the material available had been found.

The Library Board, as announced in its report published in the March, 1920, Journal, decided early in 1919, to undertake the recataloging of all the material. As no uniform scheme for classifying the books was in use, much reclassification is also involved. A special corps of workers was assembled for the task and since the fall of 1919, the energies of the staff have been chiefly concentrated on this work.

As it is believed that the methods adopted will not only fix the practise of the Library for years to come, but may also become the standard for other engineering collections, every

effort has been made to adopt methods that will both meet present needs and also provide for future developments, so far as these can be predicted. This has involved the sacrifice of speed, but as the work is intended to be permanent, basic soundness has been considered the prime quality.

At present, approximately one-fourth of the work is done. The recataloged material includes all the publications of the past four years, and those classes of the older material most in use; among others, the periodicals, and the geological material for many states. Work on the remaining material is proceeding class by class, the most important classes being treated first.

The following extracts from a report submitted in October by Miss Margaret Mann, the Chief Cataloger, give detailed information on certain phases of the problem. They will, it is hoped, be of interest to many members, as showing the results obtained, the difficulties to be overcome and the results anticipated when the work is finished.

Extracts From Report

The Chief Cataloger came to the Library May 1, 1919 and after devoting one month of study to the problem, began the search for a staff of assistants. The staff was accumulated gradually. Real work did not begin until September, 1919.

During the year from September, 1919 to October, 1920, 23,204 books have been completely cataloged and 31,679 volumes have been handled in order to catalog these 23,204. The 23,204 volumes represent 5,000 titles.

This has been accomplished with a staff averaging ten.

Some Interesting Statistics

Volumes	
New volumes cataloged	2,194
Old volumes recataloged	21,010
Volumes added to existing records	2,499
Duplicate volumes listed	4,676
Volumes withdrawn from the Library	1,300
Total volumes handled	31,679
Additions to the New Catalog	
Titles represented	5,000
Subjects "	10,301
Catalog cards added	26,637
Index	9,052
Cards	
Cards Typed	43,024
Library of Congress cards used	10,769
Total cards filed in official and public catalogs	53,793

Summary

23,204 volumes represent 5,000 titles. From these 5,000 titles we have made available 10,301 subjects. To catalog 23,204 volumes, or 5,000 titles, completely by author and subject, we have had to handle 31,679 volumes, which has necessitated the preparation and filing of 53,793 cards and the typing and filing of 840 sheets into loose-leaf binders.

The Results to be Gained by Recataloging

1. *Making the resources of the Library available.*

By the recataloging the varying methods of cataloging and classifying formerly used by the societies are being eliminated, bringing the collection together into a logical whole.

Much of the material handled by the cataloging staff this year cannot be called recataloging, because many classes of books now in the Library have not, up to this time, been represented in the catalog.

Such difficult work as the cataloging of the State and Federal documents is quite new to this Library. Some of the most valuable material covering such subjects as Mining, Geology, Foreign Trade, Water Supply, Road Engineering, etc., is to be found in the reports and bulletins issued by State surveys, commissions and experiment stations.

Publications emanating from the various Bureaus are being analyzed and made available for the first time.

2. *The Library will have a catalog,* which can be printed in small but complete units, small enough to be included in our own society journals.

Unlike an alphabetical catalog the classified catalog now in process of making can be used and printed by subject. It is so arranged that one class such as Hydraulic engineering is complete in itself and is not scattered under Pumps, Dams, Water flow, etc. An alphabetical index takes care of Pumps, Dams and Water flow, while the whole class of Hydraulic engineering remains as a unit.

Should a smaller class be needed, such as Dams, this will also be found to be a complete unit.

3. *Weak spots in the collection* will be revealed and records furnished for filling in the gap.

Until the books are combined under one classification it is quite impossible to see wherein the Library is weak.

4. *The catalog will establish a system of classifying engineering literature* which can be applied not only to books but also to the indexing of periodicals.

5. *We will have compiled an alphabetical key* to the classification which, if published, will enable any engineer to index his own library, and his own periodicals, by the most approved international method at a minimum cost.

This has never before been accomplished by any library or any individual and its completion will see a real contribution to engineering literature. It is an aid which engineers are seeking.

The possibilities for completing the work seem most hopeful. This year can only be called preparatory to what we should accomplish later on. We have had to lay our plans, build the foundations and train our staff. The succeeding months should show a steady increase in our output and a greater ease in our accomplishment of results.

The cooperation offered on all sides has helped to lighten the burden and keep up our courage.

The cataloging staff have given faithful service during a very difficult year.

BOOK NOTICES (FROM OCTOBER 1 to 31 1920)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or text of the book.

All books listed may be consulted in the Engineering Societies Library.

The Chemical Analysis of Steel-Works' Materials.

By Fred Ibbotson. Lond. & N. Y., Longmans, Green & Co. 1920. 296 pp., tables, 9 x 6 in., cloth $7.50.

This work is a revised edition of those portions of The Analysis of Steel-Works' Materials, published in 1902, which treated of the analytical chemistry of the raw materials and finished products of ferrous metallurgy. The material on pyrometry and microscopy is omitted from the revised book.

The Coal Trade.

The Year Book of the Coal and Coke Industry. By Sydney A. Hale. 47th annual edition, 1920. N. Y., The Estate of F. E. Saward, 352 pp., tables, 8 x 6 in., cloth, $4.

The present volume is, the compiler states, the largest in size and the widest in scope yet issued. It includes a variety of statistical tables of interest to those in the coal industry, brought to the latest possible dates, and information showing the development of the industry during the past year. The book contains statistics of production, exports, imports, costs, prices, ocean rates, wages and similar matter, as well as reviews of important occurrences.

Common Sense and Labor.

By Samuel Crowther. Garden City, N. Y., Doubleday, Page & Co., 1920. 284 pp., 8 x 5 in., cloth, $2.

The author discusses the cause of present day dissatisfaction between workmen and employers, the various remedies that have been suggested, and the results obtained in actual cases. Written in readable style, and of interest to employers.

Condensed Catalog of Mechanical Equipment.

Comprising Condensed, Uniformly Presented and Illustrated Catalog Information Covering the Products of Manufacturers of Various Classes of Mechanical Equipment, with General Classified Directory . . .and Consulting Engineers' Directory. Tenth annual volume, October 1920. N. Y., American Society of Mechanical Engineers, 1004 pp., illus., 9 x 6 in., cloth $4.

The tenth edition of this catalog and directory of mechanical equipment and consulting engineers follows the established lines although the data on A. S. M. E. standards have been omitted from this issue. Five hundred and nine firms are represented by condensed catalogs of their products, this section being eighty pages longer than in 1919. The directory of mechanical equipment, in which manufacturers are listed under products, is 10 per cent larger, and the directory of consulting engineers covers 60 per cent more pages than before. Various improvements have also been made to facilitate convenient reference.

ELEMENTS OF ENGINEERING THERMODYNAMICS.

By James A. Moyer, James P. Calderwood and Andrey A. Potter. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 216 pp., illus., tables, folded chart, 9 x 6 in., cloth, $2.50.

This treatise is an extension of a briefer work entitled "Engineering Thermodynamics", by James A. Moyer and F. A. Calderwood. It is intended to bring out the fundamental principles of the subject, particularly for use in technical college where special courses on steam turbines, internal combustion engines, refrigeration and other applications of thermodynamics can be given.

Additions and changes have been made to the original material, to make the book better adapted to special requirements.

ENGINEERING ELECTRICITY.

By Ralph G. Hudson. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall Ltd., 1920. 190 pp., illus., tables, 9 x 12 in., cloth $2.50.

This text represents the lectures given at the Massachusetts Institute of Technology to those technical students who are not specializing in electrical engineering. The course covers the general principles of electrical engineering and magnetism most frequently applied in engineering practise.

FINANCIAL ENGINEERING.

A Text for Consulting, Managing and Designing Engineers and for Students. By O. B. Goldman. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1920. 271 pp., illus., tables, 9 x6 in., cloth, $3.50.

Contents: Cost Segregation; Fundamental Financial Calculations; Basic Costs; Vestances; Unit Cost Determination; Determination of Size of System for Best Financial Efficiency; Determination of Type and Size of Units.

The author of this treatise has in mind the practising engineer, interested in installing plants that will have the highest financial efficiency, although not necessarily the highest mechanical efficiency. The book is therefore an exposition of methods for determining the comparative value of the things which the engineer must use, and the financial efficiency of undertakings.

THE IRON ORES OF LAKE SUPERIOR.

Containing Some Facts of Interest Relating to Mining and Shipping of the Ore and Location of Principle Mines. Fourth edition, with original maps of the ranges. By Crowell & Murray. Cleveland, The Penton Press, 1920. 301 pp., illus., maps, tables, 9 x 6 in., cloth, $5.

This is a concise account of the development and present status of the mining properties of the Lake Superior region and of the iron mining industry in general. The introductory chapters treat of the early history of the region, its geology and mineralogy, and the methods of drilling, exploring, mining and analyzing the ores, accompanied by extensive records of the average analysis of the various ores and a chapter on their valuation. The remaining and larger portion of the book is given to brief descriptions of the individual mines, accompanied by sketch maps of each range.

THE LOCOMOTIVE UP TO DATE.

By Chas. McShane. Revised by the author. Chic., Griffin & Winters, 1920. 893 pp., illus., plates, 9 x 6 in., cloth $5.

The first edition of this book appeared over twenty years ago, and found popularity as a clear explanation of the construction, operation and repair of the locomotive, suited to the needs of railway men without special engineering knowledge. The present edition has been revised, enlarged, and partly rewritten, to meet modern conditions.

MINE GASES AND VENTILATION.

Textbook for Students of Mining, Mining Engineers and Candidates Preparing for Mining Examinations, Designed for Working out the Various Problems that Arise in the Practise of Coal Mining, as They Relate to the Safe and Efficient Operation of Mines. By James T. Beard. Second edition revised and enlarged. N. Y., & Lond., McGraw-Hill Book Co., Inc., 1920. 433 pp., illus., plates, tables, 8 x 6 in., flexible cloth, $4.00.

The present edition of this treatise on mine ventilation has been much enlarged. New Sections on Safety Lamps, Oils, Breathing Apparatus and Rescue Work have been added, together with numerous tables. The endeavor has been to make the book a standard work on the subject.

MINERALOGY.

An Introduction to the Study of Minerals and Crystals. By Edward Henry Kraus and Walter Fred Hunt. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc., 1920. 561 pp., illus., 9 x 6 in., cloth, $4.50.

The aim of the authors of this work has been to present in a direct, simple manner, and within a single volume, the essentials of the various phases of the science. The conventional line drawings of crystals have been largely replaced by photographs of models, natural crystals and minerals, such as are actually handled in the laboratory. An attempt has also been made to vitalize the subject by including chapters on the importance of mineralogy, on gems and precious stones, and on the production and uses of the important economic minerals. Numerous photographs and short sketches of noted mineralogists have been added. The book treats of crystallography, blowpipe analysis and descriptive mineralogy, and has determinative tables.

FUNDAMENTAL PRINCIPLES OF ELECTRIC AND MAGNETIC CIRCUITS.

By Fred Alan Fish. First edition. N. Y. & Lond., McGraw-Hill Book Co., 1920. 194 pp., illus., 9 x 6 in., cloth $2.75.

This volume is intended as an introduction to the study of electric power machinery and transmission. It discusses the principles that the author considers fundamental, is intended for undergraduate students, and therefore does not go deeply into the physical and mathematical theory of electricity, nor include all the possible variations in conditions which might affect the application of the principles as stated.

GEOLOGY OF THE NON-METALLIC MINERAL DEPOSITS OTHER THAN SILICATES.

Vol. I. Principles of Salt Deposition. By Amadeus W. Grabau. First edition. N. Y. & Lond., McGraw-Hill Book Co., Inc., 1920. 435 pp., illus., maps, tables, 9 x 6 in., cloth, $5.00.

This book, the author states, is essentially a treatise on applied stratigraphy. It deals with non-metallic mineral deposits exclusive of silicates, but with merely incidental consideration of hydrocarbons and some native elements, which will be treated more fully later. It may be called a handbook of salt geology, if this name is understood to include nitrates, borates, phosphates and similar deposits. Emphasis is laid upon the geological relationships of these deposits and the conditions under which such deposits form are studied.

INDUSTRIAL HOUSING.

With Discussion of Accompanying Activities; Such as Town Planning—Street Systems—Development of Utility Services—and Related Engineering and Construction Features. By Morris Knowles. First edition, N. Y. & Lond., McGraw-Hill Book Co., Inc., 1920. 408 pp., illus., tables, 9 x 6 in., cloth, $5.00.

The author endeavors to develop the things which must be considered in order to provide not merely houses but homes, with all the attendant attributes of a living and livable town, and his book is the result of a realization that the preparation of a successful town plan and the development of a contented industrial community are dependent upon the action of many agencies and require the coordination of men of many professions. Although the work of an engineer, the book is not a treatise on technical practise, but is intended to represent the views of experts in architecture, town planning, landscape gardening, engineering, sanitation, public utilities, building, real estate, civics and business, for whom, together with city officials, the book is intended.

MODERN PULP AND PAPER MAKING.

A Practical Treatise. By G. S. Witham, Sr. N. Y., Book Dept. The Chemical Catalog Co., Inc., 1920. 599 pp., illus., 9 x6 in., cloth, $6.

This treatise is the work of a writer with long practical experience in the industry, and is intended to fill the need for a practical work on paper manufacture as carried on in America,

that is not too abstruse and technical for the average papermaker, but which is thorough enough to be of real value. The book describes the equipment and processes in actual use, and also treats of plant design and personnel.

A Practical Treatise on Engineering and Building Foundations including Sub-aqueous Foundations.

Vol. I. Ordinary Foundations. By Charles Evans Fowler. Fourth edition. N. Y., John Wiley & Sons, Inc.: Lond., Chapman & Hall, Ltd., 1920. 531 pp., illus., plates, tables, 9 x 6 in., cloth, $5.

The present treatise, which will include three volumes when completed, is a revision and expansion of the author's former book entitled "Sub-aqueous Foundations." Much has been added on the masonry of retaining walls, abutments, bridge piers and other classes of engineering foundations, including foundations for buildings. Volume one is a comprehensive treatment of ordinary foundations, covering piles, pile driving, the masonry of retaining walls, abutments and bridge piers. Volume two will treat of caissons and deep foundations generally, building foundations, underpinning, and foundations for dams, sea walls, drydocks and locks. Volume three will cover the design and construction of harbors.

The Practise of Lubrication.

An Engineering Treatise on the Origin, Nature and Testing of Lubricants, their Selection, Application and Use. By T. C. Thomsen. First edition, N. Y. & Lond., McGraw-Hill Book Co., 1920. 607 pp., illus., 9 x 6 in., cloth.

After a brief, practical description of commercial oils, fats and greases, the author describes the chemical and mechanical tests used and explains the laws of friction. Methods of lubrication are then described. The greater portion of the book is given to a discussion of the selection and use of lubricants for specific types of machinery, covering all classes of machines. Oil recovery, purification, storage and distribution, oils for cutting and for transfomers are also discussed. The viewpoint throughout is that of the engineer rather than the chemist.

Tin, Sheet-Iron and Copper-Plate Worker.

By Leroy J. Blinn. New enlarged edition. N. Y., Henry Carey Baird & Co.. Inc., 1920. 334 pp., illus., tables, 8 x 5 in., cloth, $3.

A revised edition of a well-known work on the working of sheet-metal, containing rules for laying out work, recipes for solders, cements, and lacquers, as well as the tables and other data used by the mechanic.

SECTION AND BRANCH MEETINGS

PAST SECTION MEETINGS

Atlanta.—October 29, 1920. Business meeting, followed by presentation of an interesting moving picture of the Georgia Railway and Power Company's hydroelectric development on Tallulah River. After the meeting adjourned refreshments were served by the Entertainment Committee. Attendance 30.

Baltimore.—October 15, 1920, Lexington Street Building. Mr. Herbert A. Wagner, President, Consolidated Gas, Electric Light and Power Company, gave an introductory talk on the progress of "Modern Illumination," followed by an illustrated lecture on "Methods of Industrial Lighting," by Mr. Ward Harrison, of the National Lamp Works, Cleveland, Ohio. The meeting ended with the serving of light refreshments through the courtesy of the Consolidated Gas, Electric Light and Power Company. Attendance 100.

Chicago.—October 20, 1920. Fullerton Hall, Art Institute. Subject: "Origin and Energy of the Lightning Flash." Speaker Dr. C. P. Steinmetz. Attendance 500.

Cincinnati.—October 14, 1920. Assembly Hall, Union Gas & Electric Company. Subject: "Time and Space in terms of Einstein's Theory of Relativity." Speaker: Dr. Saul Dushman of the Research Laboratory of the General Electric Company. Attendance 58.

November 11, 1920. Assembly Hall, Union Gas & Electric Company. Subject: "Automatic Substation Equipment." Speaker: Mr. C. A. Butcher of the Westinghouse Elec. & Mfg. Co. Attendance 45.

Cleveland.—October 19, 1920. Subject: "Telephone Service for Cleveland." Speaker: Mr. Charles P. Cooper. Attendance 112.

Denver.—October 16, 1920. Metropole Hotel. After the usual dinner the Chairman opened the meeting with the announcement of committee appointments. The speaker of the evening was Mr. M. G. Brannan of the Riley Underfeed Stoker Co., on the subject of: "Stokers and Their Application." Attendance 40.

Detroit-Ann Arbor.—October 8, 1920. Board of Commerce. First dinner and meeting of the season. The general object of the meeting was to get the members of the section acquainted with each other and to secure their opinion as to ways and means of increasing the value of the section to its members. Attendance 80.

October 22, 1920, Board of Commerce. Round table talk. Subject: "Characteristics and Applications of Transformers." The discussion was led by Professor Parker. Attendance 45.

Ithaca.—October 29, 1920. Franklin Hall, Cornell University. Speakers: Professor V. Karapetoff on "High Spots in the A. I. E. E. 1920 Convention"; and Dr. Edw. L. Nichols on "Personal Recollections of Oersted and Ampere 1820." Attendance 102.

Lynn.—November 3, 1920. Subject: "Problems Involved in Large Generating Stations." Speakers: Messrs. Probst, Sittinger, Mars and Schiller. Attendance 180.

Philadelphia.—November 8, 1920. Engineers' Club of Philadelphia. Subject: "Recent Progress in Radio Telephony.". Speaker: Dr. H. W. Nichols, Research Engineer in Charge of Radio Research, Western Electric Company. Attendance 146.

Pittsburgh.—October 12, 1920. Auditorium, Chamber of Commerce Building. Subject: "Induction-Motor Core Losses" (paper by P. L. Alger and R. Eksergian). Speaker: Mr. P. L. Alger. Attendance 85.

Portland, Ore.—September 28, 1920. University Club. Subjects: "Actual Accomplishments of the California Cooperative Campaign," by Miss Clotilde Grunsky, E. E., and "The Origin and Purpose of the Northwest Electric Service League," by Mr. A. C. McMicken. Attendance 75.

October 19, 1920. University Club. Paper: "Scientific Illumination and its Practical Application." Speaker: Mr. F. H. Murphy, Illumination Engineer, Portland Railway, Light and Power Company. Attendance 80.

Providence.—November 2, 1920. Providence Engineering Society. Joint meeting with the Power Section of the Providence Engineering Society. Subject: "Public Utility Rate Making." Speaker: Mr. Jesse E. Gray, Assistant Secretary of the Narragansett Electric Lighting Company. Attendance 45.

Schenectady.—October 15, 1920. Edison Club Hall. Subject: "Some Ice Problems and Their Solutions." Speaker: Mr. John Murphy, Department of Railways & Canals, Ottawa, Ontario, Canada. Mr. Murphy divided his subject into two parts—first, ice conditions as they are, with pictures illustrating actual conditions and moving pictures showing how frazil and anchor ice are formed; second, methods for preventing ice in waterwheels, forebays and penstocks, illustrated with pictures. Attendance 275.

Seattle.—October 19, 1920. Arctic Club Assembly. Subject: "The Power Indicating and Limiting System in Use on the

Western Division of the Chicago, Milwaukee & St. Paul Railway." Speaker: Mr. C. Anderson, of the Westinghouse Electric & Mfg. Company. Attendance 80.

Spokane.—October 21, 1920. Davenport Hotel. Dinner followed by joint meeting with Associated Engineers. Subject: "Industrial Research." Speaker: Dr. C. E. Magnusson. Attendance 22.

Syracuse.—October 8, 1920. Technology Club. Organization meeting and election of officers as follows: Chairman, Edward T. Moore; Secretary, Frank Simpson.

Toronto.—October 15, 1920. Chemistry Building, Toronto University. Subject: "The Manufacture of Electrical Wires and Cables." Speaker: Mr. H. P. Young, Chief Engineer, Canada Wire & Cable Co. Attendance 88.

October 29, 1920. Toronto University. Subject: "High-Frequency Multiplex Telephony." Speaker: Dr. Chas. R. Culver, of the General Engineering & Construction Co., Ltd. Attendance 134.

November 10, 1920. Hart House, University of Toronto. Social meeting, including moving pictures, music, a mathematical contest, short speeches by several members of the section, and refreshments. Attendance 117.

Utah.—October 15, 1920. Commercial Club. Mr. H. T. Plumb, official delegate to the Annual Convention, presented an interesting paper on "The Outstanding Features of the 1920 Convention." The paper was divided into three parts: (1)Institute Affairs, (2) Impressions of Delegates, (3) Technical Papers. Attendance 20.

Vancouver.—September 24, 1920. Committee appointments. Mr. R. F. Hayward reported his impressions of the Portland Convention in July and briefly discussed the papers presented there. Attendance 21.

Washington.—October 12, 1920. Cosmos Club, Washington, D. C. Dr. F. A. Wolff of the Bureau of Standards gave an illustrated lecture on "Functionalized Circuit Diagrams." Following this Mr. Walter E. Brown of the Telephone Section of the Bureau of Standards, gave an illustrated talk on "Telephone Service." Attendance 74.

PAST BRANCH MEETINGS

University of Arkansas.—October 5, 1920. Engineering Hall. Business meeting. Subjects discussed: "Things an Engineer Should Know," by Professor Ripley; "The Electrification of the Chicago, Milwaukee, and St. Paul Railroad." by P. L. Mardis of the Westinghouse Elec. & Mfg. Co. Attendance 40.

November 2, 1920. Engineering Hall. Subject: "The Construction of High-Tension Transmission Lines." Speaker: R. P. Hart. Attendance 14.

University of California.—October 20, 1920. Subject: "Individual Drive as Applied to Machine Tools and the Advantages of Motor-Generator Sets and D-C. Equipment." Speaker: Mr. F. L. Boissonault of the Westinghouse Elec. & Mfg. Co. Attendance 28.

November 3, 1920. Subject: "The Financing of Public Utilities." Speaker: Dean Hatfield. Attendance 34.

California Institute of Technology.—October 26, 1920. Election of officers as follows: Chairman, Ray W. Preston; Secretary, Lawrence F. Chandler. Attendance 14.

University of Cincinnati.—October 12, 1920. Engineering Building. Professor C. B. Hoffmann gave an informal talk on the A. I. E. E. work at U of C. Attendance 82.

October 19, 1920. Engineering Building. Subject: "What 'Convenience Outlets' Mean to the Trade and Power Company." Speaker: Mr. L. T. Milnor, President of the Milnor Elec. Co., of Cincinnati. Attendance 87.

October 26, 1920. Engineering Building. Subject: "What We Mean by Electric Service." Speaker: Mr. W. W. Freeman, President of the Union Gas & Elec. Co. Attendance 87.

Clemson Agricultural College.—October 12, 1920. Subject: "Recent Electrical Developments." Speaker: Professor F. T. Dargan. Attendance 99.

November 9, 1920. Subjects: "Hydroelectric Power," by Messrs. Moore and Gower; "The Hundredth Anniversary of Electromagnetics," by G. M. Riley. Attendance 50.

University of Colorado.—October 14, 1920. Engineering Building I. Election of officers as follows: Chairman. T. H. Clarke; Secretary, C. L. Kerr; Treasurer, W. F. Suess. Attendance 37.

University of Iowa.—November 1, 1920. Physics Building. Election of officers as follows: Chairman, W. C. Reilly; Vice-Chairman, R. K. Klatt; Secretary-Treasurer, A. Schump. Attendance 30.

University of Kansas.—October 6, 1920. Marvin Hall, K. U. Subject: "The purposes of the A. I. E. E. Association and its Meaning to Electrical Engineers." Speaker: Professor Shaad. Attendance 90.

October 20, 1920. Marvin Hall. Meeting of the different engineering societies. Lecture on "Concrete" was given.

Kansas State Agricultural College.—October 7, 1920. Addresses by Professor Reid and President Joss. Mr. G. W. Fisher spoke on "A Summer's Experience with the General Electric Company." Attendance 115.

October 15, 1920. Subjects: "Two Summers' Experience with the Long Lines Department of the American Telephone & Telegraph Company," by R. S. Breese; "A Summer's Experience with the Commonwealth Edison Company of Chicago," by M. J. Lucas; extemporaneous talk on the General Electric Company, by C. F. Joss. Attendance 126.

Lehigh University.—October 21, 1920. Paper: "The Electron Theory of Electricity." Speaker: Professor S. S. Seyfert. Attendance 77.

University of Maine.—October 27, 1920. Lord Hall. Subjects: "Work with the American Telephone Company," by Ralph M. Kendall; "Illumination," by Professor W. E. Barrows. Attendance 24.

Massachusetts Institute of Technology.—November 4, 1920. Subject: "Electrical Public Utilities Operation." Speaker: Mr. L. L. Elden, Boston Edison Company. Attendance 53.

Michigan Agricultural College.—October 21, 1920. Professor A. R. Sawyer gave a short talk concerning the foundation of the student branches and their relationship to the Institute. Professor L. S. Foltz also gave a very interesting talk on "Testing of Rail Bonds." Attendance 47.

November 9, 1920. Mr. R. D. Wyckoff presented the theory and operation of the oscillograph in a most interesting manner. The lecture was supplemented by many sketches and diagrams and was followed by an actual demonstration of the "Duddell Oscillograph." Attendance 54.

School of Engineering of Milwaukee.—October 16, 1920. Mr. A. W. Berresford, President of the A. I. E. E., gave a very interesting talk on "The Ideals of the Institute." Mr. H. W. Cheney, Chairman of the Milwaukee Section of the Institute, delivered a short talk on the aim and purpose of the Milwaukee Section. Mr. A. Simmon, of the Cutler-Hammer Mfg. Co., gave a short address pointing out the progress of the School of Engineering Branch and the advantages of such an organization to students. Attendance 154.

University of Minnesota.—October 29, 1920. Election of officers as follows: Chairman, Basil C. Maine; Secretary, Ludvig C. Larson; Treasurer, A. W. Wilson. Attendance 30.

University of Missouri.—October 18, 1920. Engineering Building. Subject: "The Application of Electricity to Marine Engineering." Speaker: Mr. R. A. Beekman, of the General Electric Company. Attendance 115.

University of Nebraska.—November 3, 1920. E. E. Building. Subject: "District Steam Heating." Speaker: Mr. I. B. Starr of the Lincoln Traction Co. Attendance 28.

North Carolina State College.—October 5, 1920. Business Meeting. Attendance 24. Paper: "The Electromagnet." Authors: Messrs. Guirkin, Wallace and Inscoe. Attendance 44.

October 19, 1920. Mr. Mann gave a talk on the proposed features of the Electrical Show. Capt. Cox spoke of the benefits derived from being members of the A. I. E. E. Attendance 30.

Ohio Northern University.—October 20, 1920. Dukes Memorial. Subjects: "Value of Laboratory Work to an Engineer," by Professor F. L. Berger; "Oscillograph Demonstration," by Professor F. W. Molitor. Attendance 51.

Ohio State University.—October 28, 1920. Subject: "Electrical Power and Steam Power." Speaker Dean Hitchcock. Attendance 27.

University of Oklahoma.—October 7, 1920. Engineering Building. Business meeting. Attendance 34.

Oklahoma Agricultural and Mechanical College.—November 4, 1920. Subjects: "Electrical Possibilities in South America," by Mr. Walter Rey; "The Importance of Electrical Engineering in Foreign Markets," by Mr. Edward Sadlor; "Installation of Electrical Mine Hoists in South Africa," by Mr. G. C. Wells. Attendance 18.

University of Pennsylvania.—October 13, 1920. Engineering Building. Business meeting; committee appointments. Attendance 42.

Pennsylvania State College.—November 11, 1920. Subject: "The Engineer in Big Business." Speaker: R. L. Sackett. Attendance 50.

Purdue University.—October 19, 1920. Subjects: "Sound Ranging in the World War," by Professor L. D. Rowell; "History of the Purdue Union Movement," by Dean Coulter. A movie comedy was also shown. Attendance 95.

Stanford University.—October 7, 1920. Business meeting. Attendance 13.

Syracuse University.—October 5, 1920. Election of officers as follows: Chairman, Floyd C. Barnes; Secretary, Florent E. Verdin. Attendance 14.

October 12, 1920. Paper: "Electrical Equipment for Locomotives." Author: Mr. Wilson. Attendance 13.

October 19, 1920. Subject: "Distribution System of Syracuse Lighting Company." Speaker: Mr. Smith. Attendance 13.

University of Virginia.—October 14, 1920. Subjects: "The Purpose and Advantages of being a Student Member," by Professor W. S. Rodman; "My Experiences with the Appalachian Power Company as a Maintenance Man," by W. T. Straley; "Taking Data on Connected Loads," by H. M. Harris. Attendance 24.

Virginia Military Institute.—September 29, 1920. Paper: "The Steam Engine." Speaker Mr. Land. Attendance 22.

October 30, 1920. Subject: "Mobile Ordnance Repair Truck." Speaker: Lieut. Doggett, U. S. A. Attendance 23.

University of Washington.—October 5, 1920. Dr. C. E. Magnusson spoke on "The Benefits to the Student of Joining the Local Branch of the A. I. E. E." One reel of film on the Butte, Anaconda & Pacific Railroad and two reels on the Panama Canal were shown by courtesy of the General Electric Company. Attendance 61.

West Virginia University.—October 20, 1920. Mechanical Hall. Papers read: "Electric Welding," by F. Donally; "Armature Reactions in Alternators," by C. M. Harmon; "Flood Lighting," by P. D. Brown; "Generators for 3000-volt D-C. Railway," by R. B. Walker. Attendance 13.

University of Wisconsin.—October 20, 1920. Engineering Building. Business meeting. Attendance 57.

November 3, 1920. Engineering Building. Subject: "Power Plant Surveying." Speaker: Mr. A. Taranger (student). Attendance 30.

Yale University.—October 26, 1920. Subjects: "The Electric Railway Convention," by H. V. Bozell; "Utility Problems in Connecticut," by A. E. Knowlton; "Technical Teachers at the Westinghouse Works," by W. B. Hall; "Recent Developments in Radio," by H. M. Turner, "Recent Acquisitions to the Laboratory of Industrial Control Apparatus," by L. W. Morrow; "Recent European Trip," by Professor C. F. Scott. Attendance 53.

ENGINEERING SERVICE BULLETIN

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

SERVICES AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after an interval of three months, during this period names and records will remain in the active files.

NOTE.—All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to the ENGINEERING SOCIETIES EMPLOYMENT BUREAU, 33 West 39th Street, New York City, the employment clearing house of the National Societies of Civil, Mining, Mechanical and Electrical Engineers.

MEN AVAILABLE

ARMY OFFICER (Major) having fifteen years' experience prior to the war in telephone engineering, cable installations, including factory tests and d-c. light and power systems, desires position with manufacturer or firm. Experienced as administrator, executive and office manager. References if desired. E-2409.

ENGINEERING SALES, connection desired with progressive organization, preferably on Atlantic coast. Successful experience sales, construction, design, electric furnaces, power plants, public utilities. Technical graduate, good personality, energetic, resourceful and dependable, executive and publicity experience. Wide-awake, progressive man seeks new connection with broader possibilities. E-2410.

ELECTRICAL ENGINEER, college graduate, age 42, 14 years' experience, in the design and installation of generating and substations with biggest utility companies in New York and Ohio. Special experience in all kinds of substations, d-c. and a-c., indoor and outdoor up to 130,000 volts. Available November 1st. E-2411.

SALES ENGINEER, Technical graduate, age 24. At present connected with concern manufacturing elevator equipments, desires new connection where results are used as a basis for advancement. Has had G. E. Test and general engineering experience. Position desired vicinity of New York City. E-2412.

ELECTRICAL ENGINEER, or Central Station Executive. Cornell graduate, eighteen years experience, manufacturing, construction, operation. Have been general superintendent of two large hydroelectric systems in the East. Available now because of service in the Army and temporary engagement since. E-2413.

GRADUATE of technical school, age 23. Three years college training, wants electrical work anywhere; preferably installation. At present with electrical manufacturing concern. Can give good reason for leaving, also reference. E-2414.

GRADUATE ELECTRICAL ENGINEER, B. S. degree, Armour Institute '17. Four years experience, efficiency and production engineering, engineering investigations, leading to the introduction of new and improved manufacturing

methods with two leading concerns. Permanent positions in Chicago or immediate vicinity affording an expanding future desired. Salary $3,000. Available upon short notice. E-2415.

Electrical Engineer, age 31; married. Technical graduate of good standing, highly trained in modern practise. Exceptional experience in power plant, substation, power transmission and industrial engineering. For the past four years connected in executive capacity with the largest power plant and industrial equipment installation. Best of references from former employers furnished upon request. E-2416.

Superintendent and Construction Engineer, 10 years experience in construction and operation of hydroelectric and steam power stations, transmission lines and substations. Seeks position as Construction Engineer or Superintendent of Power Stations. At present Superintendent of steam plant in the tropics, speaks Spanish and experienced in handling construction gangs. Desires foreign service, preferably in Spanish countries or S. A. Age 33 years, married. Available 30 days notice. E-2417.

Executive Engineer with broad engineering, executive and modern business training, desires connection with industrial or public utility corporation or banking concern. Experience includes industrial and public utility engineering, appraisals, financial examinations and reports; studies of organization and management. Electric railways, design, construction and operation, and power transmission. Age 42. Degree E. E. E-2418.

Electrical Engineer. Age 26. Graduate Syracuse University 1917. Electrical testing experience. Familiar with electrical equipment of steel mills, modern central station operation, main drives, (reversing type) and all branches of industrial engineering. E-2419.

Technical Graduate, I. C. S; Associate, age 29; married, foreign born. Eight years experience in maintenance, including two years G. E. test of E. R. equipment and 18 months substation and switchboard operating. Desire position leading to permanency, with industrial or operating company. Interested in electrical calculation, no office experience, willing to undergo training if position require. A-1 reference, ambitious. Salary $140.00, available January 1st. Willing to go anywhere. E-2420.

Public Utility Manager. Construction engineer and operating manager on electric power properties for past twelve years. Accustomed to large responsibility and qualified in all phases of public utility management; operating, financing, accounting, publicity, reports, appraisals, design and construction. At present engaged in the South, operating or appraisal work with large concern desired. E-2421.

Electrical Engineer, desires responsible position with central station. Experienced on large systems, power stations, substations, transmission, a-c. distribution and d-c. distribution. Can supervise the making of plans, and handle construction and operating forces. Technical graduate, age 34; married. Associate member American Institute of Electrical Engineers. E-2422.

Research Engineer, with experience in developing various electrical projects, including radio, has had executive charge of extensive and important engineering work as Professor of Physics and electrical engineer, has carried on researches in three noted University Laboratories; now desires connection with large corporation planning the organization of its research department. E-2423.

Executive Engineer, capable of taking charge of development of electrical and mechanical apparatus or position as factory manager or superintendent; 35 years old. Thirteen years' experience. E-2424.

Electrical Engineer. Twelve years with electrical manufacturing companies as assistant electrical engineer. Twelve years in responsible charge of industrial electrical work for large engineering corporation. Desires responsible position with or partnership in engineering firm; executive position with large industrial organization; or to obtain capital for establishing independent engineering company. E-2425.

Sales Engineer, wish esto obtain manufacturers' agency, for direct representation of electrical and mechanical apparatus, equipment and accessories for N. Y. C. and eastern territory. E-2426.

Turbine Engineer, with nine years experience in the estimating, design and testing of steam turbines, centrifugal compressors, etc. Is thoroughly familiar with mathematical principles involved and with the latest turbine practise both stationary and marine. Would like position as chief or assistant turbine engineer, preferably with small growing concern. Location New England preferred. E-2427.

Electrical Engineer, 8 years' experience power house, substation construction and general wiring. Some teaching experience. Two years detailed as inspector of electrical material and machinery for Bureau of Steam Engineering U. S. N. Age 27; married. Available January 1st. Salary desired $2200. E-2428.

Graduate Mechanical and Electrical Engineer (1910). Ten years experience with the largest engineering corporation in advanced problems on electric power generation and distribution, as designer. "Trouble man" and research engineer. Salary $3000. Location preferred New York vicinity. E-2429.

Electrical Engineer. Associate A. I. E. E. Age 34, single. Spanish. One year G. E. test, experience in railroad work, irrigation developments, and installation of small lighting plants in South America, wants position in company operating lighting or power plant, or with manufacturing exporter. E-2430.

Electrical Engineer, age 29; married. Technical graduate. Test and railway engineer Dept. General Electric Company; Electric Engineer Railway supply house. At present engaged in organization work. Has executive ability and can handle men. Desires position as assistant superintendent in industrial concern or sales engineer. E-2431.

Engineering Executive, sales engineer, or sales representative; electrical engineer, technical graduate; married. At present connected. Experience includes electrical machine design, central station transmission, distribution, design, operation and sales engineering. East preferred. E-2432.

Electrical Engineer. Five years responsible experience; including cost, estimating, purchasing, and field work, with engineering construction firm. Two years in charge of experimental and development work and one year as manufacturing manager with large company. Experienced in factory accounting and organization. Present salary $5,000. E-2433.

Investigation Engineer. Executive consultee, adviser, and correspondent; investigations and researches in shop, laboratory, or office. Mathematical analysis, recommendations and reports; to improve tools and materials, methods, processes and equipment; for betterment of output, capacity, economy, and efficiency; in production, operation, and maintenance; estimates, specifications and costs. Stevens M. E. and Ex-Naval Engineer. E-2434.

Graduate Electrical Engineer (1916). Age 25. Four and a half years general engineering and industrial experience. At present production manager of large plant of 50,000-unit monthly capacity. Prefer to connect with growing industrial concern in Middle West as Production Manager or Assistant Works Manager. E-2435.

Electrical Engineer. Technical graduate. Two years varied test experience with large electrical manufacturer; two years design of direct-current railway motors. Age 29; not married. Position wanted with interurban operating on high-voltage direct current or with railroad contemplating electrification. Minimum salary to start $3000. Available on 30 days notice. E-2436.

Graduate Electrical Engineer, B. S. E. E. Married; age 32. Desires location in Middle West. Experienced in d-c. and a-c. installations, operation and trouble shooting, automotive electrical equipment and storage batteries, battery charging equipment, conduit work, office records and handling of men. In present location five years. E-2437.

Cornell Graduate, 1920 M. E. Desires position with a manufacturing company east of the Mississippi River in Production of Cost Department. Ten weeks experience with large manufacturing company in Production Control Department which has now been discontinued because of general curtailment. Member A. I. E. E. E-2438.

Electrical and Mechanical Engineer. Age 32. University education, business experience. Steel Plant, R. R. Metal and Rubber Goods Mfg. Several years Inspector charge tests and construction, Designer, Chief Draftsman, good organizer. Desires job as Assistant Manager, Asst. Chief Engineer, Chief Draftsman or similar. Location immaterial. E-2439.

Electrical Engineer, 26, five years manufacturing, public utility, and operating experience, desires position of responsibility with progressive concern in middle west. Technical graduate; married; chief engineer of destroyer during war. At present assistant electrical engineer with manufacturing company but desires change to strictly electrical line. Salary $225. E-2440.

HEAD OR ASSOCIATE PROFESSORSHIP in Electrical Engineering, wanted by A. I. E. E. Member. Age 33. Three years of commercial work and 8 years of teaching in large universities. Prefers work in a rapidly growing school where hard work and results count. Best references. E-2441.

ELECTRICAL ENGINEER, graduate in Mechanical and Electrical Engineering. Age 40. British subject, married; Member A. I. E. E.; G. E. Test. Twelve years experience in the installation of large water-driven units and electrical apparatus up to 110,000 volts. Recently resident engineer on large hydroelectric development in Europe. Some knowledge of Spanish. Will go anywhere. South America preferred. E-2442.

OPPORTUNITIES

ENGINEERING PERIODICAL of highest standing has opportunity for technically educated man with editorial experience, initiative and judgment, for position of responsibility. Replies should embody the essential facts. Z-2497.

YOUNG MAN with technical training. Experience in Railway distribution desired. Location Md. Z-2496.

ELECTRICAL OR MECHANICAL UNIVERSITY GRADUATES wanted for sales work with a well established electrical manufacturer in the middle west. Correspondence confidential. Give all particulars. Location Mo. Z-2456.

MECHANICAL ENGINEER for Power Stations Department, Testing Division, to have actual charge of one of new Power Plants in Pittsburgh. Z-2458.

MECHANICAL ENGINEERS, who have had several years experience in gas distribution, efficiency, compressing station operation and high pressure transportation. Four men needed. Location Penna. Z-2459. (Men to ultimately work into executive positions.)

ELECTRICAL ENGINEERS, one for Distribution Department, having experience in design, operation and construction in the field and office—the second a man who is capable of doing general engineering work in the way of design of power stations, equipment, efficiency, etc. Location Penna. Z-2460.

ENGINEER, Electrical or Mechanical, wanted by large Electrical Manufacturer, to specialize as Classification Expert. Will be expected to extend an existing classification similar to Dewey, to keep it up-to-date as the industry progresses and to develop other classification systems as needed. State full particulars, giving age, education, experience, and salary expected. Location New York. Z-2416.

STATISTICIAN, preferably an Electrical Engineer wanted by a prominent Electrical Manufacturer for collecting and compiling data on all phases of the electrical industry. Give full particulars, age, education, experience and salary expected. Location New York. Z-2417.

PRACTICAL ELECTRICAL ENGINEER along experimental lines. One who has had experience, or working knowledge of the application of electricity to household devices. Location Ohio. Z-2401.

YOUNG PROGRESSIVE ENGINEER with some experience in design of air- and oil-brake types of circuit breakers. Location Penn. Z-2407.

PHYSICIST experienced in light and sound to be in charge of laboratory for large industrial company in Connecticut. Application by letter only. Location Bridgeport, Conn. Z-2398.

YOUNG MAN TECHNICALLY TRAINED. Some practical experience for position in electric operating department of a large electric light and power company located in an Atlantic Seaboard city. Give age, experience, references and minimum salary expected at start. Z-2382.

PRACTICAL ELECTRICIAN for repairing, assembling, testing, etc. of motors, controllers and other electrical apparatus. Man about 28 years old desired. Only men who wish to work up to superintendent and stay in this line of work desired. Hours 7:45-5, noon Saturday. Location New York City. Z-2365.

CHIEF INSPECTOR for plant in middle west manufacturing electrical machinery. Work to cover both mechanical parts inspection, and electrical inspection of subassemblies. Technical man desired—thirty to forty years old who has had broad experience in manufacturing work; must be good executive and be able to coordinate his work with that of other departments without friction. Location, Ohio. Z-2370.

CHEMIST familiar with loss temperature distillation of coal treatment of by-products received from distillation, also briquetting and burning of pulverized coal. Location New York City. Z-2349.

INSTRUCTOR in Physics. Location Missouri. Z-2350.

ELECTRICAL DESIGN ENGINEERS for substation work. Must be good executives as they will have entire charge of this work. Application by letter only. Experienced men will be considered. Location New York City. Z-2353.

MECHANICAL ENGINEER; two or three years experience in power plant operation. Must be capable of working with chief engineer, of showing him how to get better results from the boiler and engine room. Installation consists of approximately 2200 boiler horse power and a total electric load of 5500 kw-hr. In addition we have numerous problems of power distribution which require the investigation of a technical man. Location New York City. Z-2357.

PRACTICAL RUBBER WIRE AND CABLE MAN, capable of laying out and organizing production of modern plant in foreign country. Give full details regarding experience, age, references, etc. in first letter. Location France. Z-2358.

SUPERINTENDENT for company manufacturing storage batteries. Must have had storage battery experience. Application by letter giving details. Location New York City. Z-2339.

PHYSICIST, Ph. D. or equal, desired by large and growing electrical research organization for field investigations, supervision of laboratory experiments, etc., necessary in connection with the development of apparatus. Young man preferred. State age, technical training, experience and salary expected. Location New York City. Z-2340.

INSPECTOR for electrical materials, especially cables. Technical graduate. Experience desirable but not essential. Salary will depend upon the experience. Young man of limited technical training if of good mental capacity will be considered. *Application by letter only.* Location New York City. Z-2341.

ELECTRICAL AND MECHANICAL ENGINEER familiar with sea-going hopper type suction dredges and hydraulic auction pipe line dredges, also with steam and gasoline tugs and launches. Will be expected to assist the Superintendent of dredges in the operation and repair of a fleet of 6 dredges with attendant plant. Applicant should give educational qualifications, employment history, age and all other pertinent information. Will be expected to undergo civil service examination for appointment to grade of Junior Engineer or Superintendent. Location Texas. Z-2323.

ELECTRICAL ENGINEER for testing and assembling d-c. and a-c. motors. Location Wis. Z-2326.

ENGINEER, technical engineer, French nationality with broad American mechanical and commercial experience in the design, construction, installation and operation of machinery. Position requires residence abroad and applicant must have a thorough command of French. Appointment will be made by letter only giving age, nationality, experience and salary desired. Z-2330.

MECHANICAL DESIGNER, with practical experience on electric switching apparatus. Permanent work for the right man. State age, experience, education and salary expected. Location Penn. Z-2322.

ELECTRICAL ENGINEER with technical training, experienced in design of electric and of generating stations, electric transmission and motor applications as applied to industrial work. Any power-plant operating experience will be considered an asset. Location Ohio. Z-2304.

ELECTRICAL ENGINEERING GRADUATE to act as an engineering assistant in connection with preparation of estimates and proposals for service extensions to transmission and distribution system. Applicant can be a recent graduate or one with a few years' experience. Location Penn. Z-2307.

JUNIOR ENGINEERS or recent graduates for power station testing. Practical experience unnecessary. Work consists of electrical testing, covering calibration of instruments and wattmeters; a-c. and d-c. relay calibration and other power plant tests, location New York City. Z-2244.

ASSISTANT PRINCIPAL OF ELECTRICAL ENGINEERING with practical knowledge of telegraphy and telephony, also knowledge of wireless desirable. Must be able to answer technical letters, editing, etc. along these lines. Permanent position. Location Scranton, Pa. Z-2192.

FACTORY MANAGER. Polyphase Motor Manufacture. Expansion of facilities and rearrangement of duties have left open position of Factory Manager. Satisfactory record of results accomplished must be submitted, including production, and indicating a thorough familiarity with economical design and manufacture. This is an excellent opening for a man of the proper qualifications, and first communication should give complete information as to ability, salary expected, etc. Only those of proved ability will be considered. Location Michigan. Z-1620.

INDUSTRIAL PHYSICIST or Engineer interested in research or electrical control problems. Location Middle West, salary according to training and experience. Location Wisconsin. Z-1525.

INDUSTRIAL PHYSICISTS. An established research laboratory of well-known manufacturer offers positions to qualified scientific men who have research ability. One or two men of scientific training in physics and experience in research are desired. There is also position open for a physicist with less experience but with creative ability. Working conditions are attractive and positions are permanent. Location Ohio. Z-558.

UNITED STATES CIVIL SERVICE EXAMINATION

SENIOR ENGINEER, Grade 2. C.E. E.E. M.E. Signal, Structural, Telephone and senior Architect. Salary—$2500 and bonus.

ELECTRICAL DRAFTSMAN. War Dept. Application received until March 7, 1921. Salary depends on experience.

SUPERINTENDENT OF ELECTROPLATING. Salary—$3000-4500. Application to close Dec. 7, 1920.

SUPERINTENDENT OF CONSTRUCTION. Application to close Dec. 7, 1920. Salary—$2500-3000.

MAN FOR BOILER AND POWER HOUSE ASSISTANT in foreign country. Applicant must be single, not over thirty-five years of age, healthy and familiar with Edgemoor type of boiler. In applying, state particulars of experience, give references and salary desired. Location India. Z-2464.

ADDRESSES WANTED

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Leo Arany, Room 201 Parkway Bldg., Broad & Cherry Sts., Philadelphia, Pa.
2.—James F. Elliott, Electric Controller & Mfg. Co., Oliver Bldg., Pittsburgh, Pa.
3.—O. H. Horner, c/o Black & Veatch, 507 Interstate Bldg., Kansas City, Mo.
4.—Wilfred Langille, Marion Station, Public Service Electric Co., Jersey City, N. J.
5.—H. S. Logan, 215 15th Street, Seattle, Wash.
6.—Leonard Morey, 1067 East 153rd Street, Cleveland, Ohio.
7.—P. J. Reese, 7th & Main Street, Royal Oak, Mich.
8.—Richard G. Thompson, Alliance Power Co., Edmonton, Alberta, Can.
9.—J. Andre Wells, Western Electric Co., 463 West Street, New York, N. Y.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED NOVEMBER 12, 1920

*ALLIS, SELDEN P., Salesman, General Electric Co., Chicago, Ill.

ARIMURA, SHINNOSUKE, Electrical Engineer, Nihon Suiroku Kabushiki Kaisha, Marunouchi Kojimachuku, Tokyo, Japan.

ARMISTEAD, FREDERICK V., Designing Engineer, General Electric Company; res., 216 Glenwood Blvd., Schenectady, N. Y.

BABCOCK, COURTLANDT W., Control Engineer, Wesinghouse Elec. & Mfg. Co., 10 High St., Boston, Mass.

BAKER, HARRY G., Supt., Clark Electric Power Company, Tooele, Utah.

BANNISTER, ALBERT Engineer-in-charge, Switchgear Tender Dept., Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, Eng.

BASU, SUSTHIR K., Electrician, The Tata Iron & Steel Co. Ltd., 106 Northern Town, Jamshedpur, India.

BELL, HUGH G., Research Engineer, Metropolitan Vickers Electrical Co., Manchester, Eng.; 514 McNair Ave., Wilkinsburg, Pa.

BLACKWOOD, ARCHIBALD G., Power House Supt., Public Works Dept., Lake Coleridge, N. Z.

BLODGETT, DAN. A., Chief Electrician, Night force, Chevrolet Motor Co., 615 W. 2nd St., Flint, Mich.

BOONE, FRANK P., Electrical Engineer, U. S. Food Products Corp., 309 Jefferson Bldg., Peoria, Ill.

BOYD, WILFRED R., Engineer, Welding Dept., Burke Electric Co., Erie, Pa.

BRADLEY, HERBERT E., Designer, New York Central Railroad, Grand Central Terminal, New York; res., 380 Hawthorne Ave., Yonkers, N. Y.

BRETTLE, ARTHUR C., Electrical Engineer, General Electric Co., Electric Bldg., Buffalo, N. Y.

BREWER, AUBREY, Shift Foreman, Cheoah Development, Tallassee Power Co., Tapoco, N. C.

BUELL, HARRY C., Industrial Engineer, Consumers Power Co.; res., 1711 Court St., Saginaw, Mich.

CHAMBERLAIN, ROBERT F., Asst. Professor of Electrical Engineering, Cornell University; res., 4 South Ave., Ithaca, N. Y.

CLARKE, ARNIM R., Service Manager, Engineering Services Ltd., 28 Dundas St. West, Toronto, Ont.

COLLINS, CHARLES E., Vice-President & General Manager, The L. E. Myers Co., 1117 Monadnock Bldg., Chicago, Ill.

CONAWAY, RALPH ARNOLD, Draftsman, Georgia Railway & Power Co., 456 Electric & Gas Bldg., Atlanta, Ga.

CREAMER, WALTER J., JR., Teacher, University of Maine, Orono, Maine.

CROSS, GORDON F., Construction Engineer, Hydro-Electric Power Commission, 190 University Ave., Toronto, Ont.

DA FONSECA TELLES, FRANCISCO E., Professor of Electrical Engineering, Escola Polytechnica, S. Paulo, Brazil, S. A.

DE MOTT, GEORGE L., 3rd Asst. Examiner, U. S. Patent Office, Washington, D. C.; res., Arlington, Va.

DICKIE, JOHN A., Electrical Engineer, Kellogg Switchboard & Supply Co., Chicago; res., Hotel Washburn, Waukegan, Ill.

*DRESSLER, ALFRED F., Instructor, New York Electrical School, 39 W. 17th St., New York, N. Y.

ELLIOTT, LEE M., Asst. to Electrical Engineer, Compania Cubana, Tatibonico, Prov. Camaguey, Cuba.

FEELY, JOHN J., General Supt., Thompson Bonney Co., 146 Pearl St., Brooklyn, N. Y.

FIELDER, EBENEZER, Substation Engineer, Public Works Dept., Addington Substation, Lake Coleridge Electrical Supply, Christchurch, N. Z.

FITZSIMONS, THOMAS S., 19 Tapscott St., Kimberley, S. Africa.

FLEMING, ELLIOTT, Electrical Engineer, Union Steamship Co., Port Chalmers, N.Z.

FRIGON, AUGUSTIN, Commissariat General de Canada, 17 Boulevard des Capucines, Paris, France.

FRIZZELL, LIONEL K., Chief Electrician, Dominion Coal Co. Ltd., Glace Bay, N. S.

FUJISAWA, KIUSABURO, Electrical Engineer, Tokio Electric Light Co., Tokio Dento Kaisha, Marunouchi, Tokio, Japan.

GARTNER, C. K., Representative, The Sperry Gyroscope Co., 40 Flatbush Ave.; res., 2511 Madison St., Brooklyn, N. Y.

GIBBONS, WALTER J., Instructor in Electrical Engineering, Defense Dept., New Zealand Government, Rotorua, N. Z.

GRAHAM, HERBERT L., Wire Chief, B. & O. R. R. Co., Jenkins, Ky.

GRIFFITH, LAFAYETTE F., Supt., Light & Power Dept., Little Rock Railway & Electric Co., Little Rock, Ark.

HASTINGS, JOHN LE ROY, Junior Student Apprentice, Motor Eng. Dept., Westinghouse E. & M. Co., E. Pittsburgh, Pa.; res., 702 So. 3rd Ave., Bozeman, Mont.

HAYNE, JOHN, Supt., Hydro Power Commission of Hanover, Hanover, Ont.

HIROTA, MITSUYOSHI, Electrical Engineer, Electric Works, Mitsubishi Zosen Kaisha, Kobe, Japan.

HOCH, ELLERY T., Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.

HOISINGTON, GEORGE P., Cable Splicer, Commissioners of Lincoln Park, Clark & Center Sts.; res., 551 Aldine Ave., Chicago, Ill.

HOLDERNESS, H. C., Transformer Engineering Dept., General Electric Company, Pittsfield, Mass.

HUANG, TUH SIU, Engineering Dept., New York Edison Co.; res., 607 W. 139th St., New York, N. Y.

HUDSON, E. L., Asst. Chief Engineer, Central Illinois Public Service Co., Harrisburg, Ill.

INOMATA, TADASU, Engineer, Electric Dept., Kawasaki Dockyard Co., Kobe, Japan.
ISAKA, KATSUZO, Chief Engineer, Nagoya Electric Light Co., Shinyanagimachi, Nagoya, Japan.
ISHIGURO, KUICHI, Electrical Designing Engineer, Mitsubishi Shipbuilding Co., Nagasaki, Japan.
ISHIKAWA, RAIJI, Engineer, Shibaura Engineering Works, 1 Kanasugi, Shibaku, Tokio, Japan.
JACKSON, JOHN B., Engineering Dept., Commonwealth Edison Co.; res., 4168 Cullom Ave., Chicago, Ill.
JONES, ORA O., Motor Inspector, Commonwealth Edison Co., 72 W. Adams St.; res., 1941 Congress St., Chicago, Ill.
JONSON, MARCUS E., Electrical Engineer, Andersen Meyer Co. Ltd., Shanghai, China.
KAMBARA, JO., Chief Electrical Engineer, Japan Nytrogen Fertilizer Mfg. Co., Minamata-mati, Asikita-gun, Kumamoto-ken, Japan.
KEISER, MORRIS, Asst. Electrical Engineer, Acoustics Section, Bureau of Standards, Washington, D. C.
KNIERIM, GUSTAVE J., Construction Foreman, Johnston Livingston & Company, Inc., Astoria, L. I., N. Y.
LAUTHERS, JAMES PEARL, Master Sargent, C. A. C. (Master Electrician), U. S. Army, Fort Andrews, Mass.
LEAHY, JOSEPH A., Polar Wave Ice & Fuel Co., Grand & Olive Sts., St. Louis, Mo.
LEVY, REGINALD M., Engineering Asst., Victorian Electricity Commissioners; res., 27 Robe St., St. Kilda, Melbourne, Aus.
MARSHALL, FRANK O., Asst. Chief Electrician, The Pullman Co., 701 Pullman Bldg., Chicago, Ill.
MIYAKAWA, RIICHI, Manager, Drafting Section, Shibaura Engineering Works, 1 Kanasugi, Shibaku, Tokio, Japan.
MOCK, FRANK CHARLES, Engineer, International General Electric Company; res., 211 Seward Place, Schenectady, N. Y.
MODRAK, PETER, Designing Draughtsman, Department of Mines, Treasury Bldgs., Brisbane, Queensland, Aus.
MONGAN, HUGH B., General Foreman & Engineer, Central Garage and Electric Supply Co., Hagerstown, Md.
MOORE, GEORGE M., Supt., Lamar Light & Power Plant, Lamar, Colo.
MOULTON-REDWOOD, WILLIAM J., Asst. Works Engineer, Canadian National Carbon Co., Ltd., Hillcrest Park, Toronto, Ont.
MURAYAMA, SHIKANOSUKE, Chief Engineer of Metallurgical Dept., Mitsui Mining Co., Ohmutashi, Fukuokaken, Japan.
MURDOCH, KENNETH B., Electric Steel Student, Crucible Steel Co. of America—Atha Works, Harrison; res., 24 Walnut St., Newark, N. J.
NISHI, TAKESHI, Asst. Professor, Elec. Engg. Dept., Tokyo Imperial University, Tokyo, Japan; 50 Church St., New York, N. Y.
ODAJIMA, SHUZO, Electrical Engineer, Toba Ship Yard; Suzuki & Co., 220 Broadway, New York, N. Y.
O'REGAN, STEPHEN P., Marine Engineer; res., 57 Harrison Ave., Port Richmond, N. Y.
PARKER, PERCY C., Distribution Engineer, Newcastle Elect. Supply Co., Carville Power Sta., Wallsend-on-Tyne; res., Newcastle-on-Tyne, Eng.
PARRA, ALBERT R., Maracaibo Electric Light Co., Maracaibo, Venezuela, S. A.
*PATTERSON, G. R., Electrical Engineer, Pittsburgh Transformer Company, Pittsburgh; res., 39 S. Howard Ave., Bellevue, Pa.
PEMBLETON, FRED W., Asst. Foreman, General Electric Co.; res., 1742 Illinois St., Ft. Wayne, Ind.
PHILLIP, HARRY J., Chief Electrician, American Cyanamid Co., Brewster, Fla.
PLATT, ALBERT H., Chief Electrician, Bullard Machine Tool Company; res., 108 Stillman St., Bridgeport, Conn.
PODESTA, ARTHUR, Head of Electrical Dept., Scriven Brothers, (Chile) Ltd., Casilla 1597, Santiago, Chile, S. A.
PRADHAN, SHRIKRISHNA R., Student Engineer, General Electric Company, West Lynn, Mass.
REYES, SALUSTIANO, Electrical Engineer, Philippine Government, Bureau of Insular Affairs, Washington, D. C.
ROBERTS, GEORGE W., Electrical Engineer, General Electric Co., Lynn, Mass.
ROMANO, MICHAEL, U. S. Navy Inspector, General Electric Co., Schenectady, N. Y.
ROSELLE, HENRY, Foreman Electrician, Iowa Railway & Light Co., Cedar Rapids, Iowa.
RUDOLPH, LOTHAR ERNST, Automatic Tel. Inspector, New Telephone Bldg., Omaha, Nebr.
*SCHAEFER, FREDERICK LEROY, Chief Engineer, Cupey Sugar Co., Cayo Mambi, Oriente, Cuba.
SCHELL, LEROY S., JR., Electrical Engineer, General Electric Company, Pittsfield, Mass.
SEAMAN, WM. E., Electrical Draftsman, Eng. Dept., New York Edison Co., 130 E. 15th St.; res., 495 E. 188th St., New York, N. Y.
SELS, HOLLIS K., General Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 122 Whitfield St., Pittsburgh, Pa.
SISLER, C. O., Asst. Supt., Lake Superior Paper Co.; res., 20 The Drive, Sault Ste. Marie, Ont., Can.
SMITH, FLOYD T., Engineer, General Electric Co.; res., 145 Elmer Ave., Schenectady, N. Y.
SMITH, MERRILL J., Electrical Engineer, with Jackson & Moreland; res., 77 Westland Ave., Boston, Mass.
STITES, SAMUEL, Salesman, General Electric Co., Nashville, Tenn.
TAYLOR, H. L., Asst. Inspector of Electrical Engineering, Provincial Government, Court House, Vancouver, B. C.
TREADWELL, LEON H., Proprietor, Treadwell Electric Co., 681 Main St., Worcester, Mass.
TYNE, GERALD F. J., Student, Rensselaer Polytechnic Institute, 2160 13th St., Troy, N. Y.
UMSTEAD, ARNER O., Supt., Electric Transmission Co. of Virginia, Big Stone Gap, Va.
UYESAKA, IWAO, Electrical Engineer, Kyushu Hydro-Electric Co., Oita, Kyushu, Japan.
VAN NESS, NEIL T., Instructor, Bliss Electrical School, Takoma Park, D. C.
VOSS, HENRY LINCOLN, Electrical Engineer, Shourds-McCormick Co., 510 Tribune Bldg., Terre Haute, Ind.
WAI, ON, Electrical Engineer, T. E. M. A., North Soochow Road, Shanghai, China.
WELCH, LEO T., Chief Engineer, Alpha Electric Construction Co., 124 Hudson Ave., Albany, N. Y.
WESTERVELT, H. M., Engineer, Ind. Control Dept., Sprague Elec. Co., Bloomfield; res., 25 Ivanhoe Terrace, E. Orange, N. J.
WHITEMAN, W. S., Insulator Specialist, Westinghouse Elec. & Mfg. Co., 1333 Candler Bldg., Atlanta, Ga.
WOOD, HOMER E., Construction Foreman, Miller Engineering Co., Seattle; res., 2514 N. Union Ave., Tacoma, Wash.
WRIGHT, MITCHELL C., Treasurer, K. W. Electric Company, 49 Lawrence St., Newark, N. J.
YAMAGUCHI, SUESABRO, Designing Engineer of Electrical Machinery, Mitsubishi Zosen Kaisha, Nagasaki, Japan.
YOUNG, WILLIS M., Lieut., U. S. Navy; res., Wenona, Ill.
Total 107,
*Former enrolled Students.

ASSOCIATES REELECTED NOVEMBER 12, 1920

DOUGLAS, JOHN F. H., Asst. Prof. Electrical Engineering, Marquette University, Milwaukee, Wis.
DRAKE, CHESTER W., General Engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., Irwin, Pa.
LUTHER, GEO. D., Manager, Seattle Branch, The Electric Storage Battery Company, 811 White Bldg., Seattle, Wash.
TAYLOR, EDWARD, Designing Engineer, Automatic Railway & Industrial Substations, General Electric Co., 923 Monadnock Bldg., Chicago, Ill.

MEMBERS ELECTED NOVEMBER 12, 1920

ALBRECHT, E. JULIUS, Engineer, Hydro-Elec. Dept., James O. Heyworth, 505 Harvester Bldg., Chicago, Ill.
BUTLER, W. H., Electrical Contractor, 163 West Seymour St., Philadelphia, Pa.
BYNG, EDWARD S., Supt., Cable & Line Consruction Dept., Western Electric Co., Ltd., N. Woolwich, London, E. 16, Eng.
DOUGHERTY, HENRY M., Construction Engineer, Chile Exploration Co., Chuquicamata, Chile, S. A.
DU RIEU, EDGAR F., Engineer for Electric Construction, Hydro-ElectricDept., Hobart, Tasmania.
HOBART, KARL E., Operating Engineer, Sanitary District of Chicago, Chicago; res., 456 Drexel Ave., Glencoe, Ill.
SCHIFF, MARTIN, Asst. Engineer, Roth Bros. & Co., Inc., 1400 W. Adams Street, Chicago, Ill.
SMITH, ROBERT W., Chief Electrical Engineer, De Beers Consolidated Mines, Ltd., Consulting Elec. Engineer, City Council, Kimberley, S. Africa.
VIALL, ETHAN, Editor, *American Machinist*, McGraw Hill Co., 36th St. & 10th Ave., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held October 25, 1920, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary

To Grade of Fellow

HAMILTON, JAMES L., Chief Engineer, Century Electric Co., St. Louis, Mo.
HIBBARD, HARRY L., Manager, Marine Dept., Cutler-Hammer Mfg. Co., New York, N. Y.
LILJENROTH, FRANS G., Consulting Engineer, E. I. du Pont de Nemours & Co., Wilmington, Del.

To Grade of Member

ANDRUS, RAYMOND J., Operating Engineer, Central Power Co., Grand Island, Neb.
BOLSER, M. O., Technical Asst., Distribution Dept., Bureau of Power & Light, Los Angeles, Cal.
DOWNTON, PERCIVAL G., Branch Manager, Electric Storage Battery Co., Minneapolis, Minn.
DRAKE, CHESTER W., General Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
FIRESTONE, SIEGMUND, Consulting Engineer, Rochester, N. Y.
GENT, RUFUS T., Plant Engineer, Hydro-Electric Power Commission, Niagara Falls, Ont.
LOCKYER, R. H. N., Engineer in Charge, West Kootenay Power & Light Co., Trail, B. C.
MILLAN, WALTER H., Supt. of Substations, Union Electric Light & Power Co., St. Louis, Mo.
NELSON, NORMAN C., Electrical Engineer, North Pacific Public Service Co., Bremerton, Wash.
NOTOMI, IWAICHI, Director, Shibaura Engineering Works, Tokyo, Japan.
POTTER, CHARLES P., Engineer in Charge, Large Motor and Transformer Engineering Depts., Wagner Electric Mfg. Co., St. Louis, Mo.
ROBERTSON, ARTHUR S., Erection Engineer, Hydro-Electric Power Commission, Niagara Falls, Ont.
ROSWELL, CHARLES M., Engineer, Charleston Consolidated Railway & Light Co., Charleston, S. C.
SIMONSON, GEORGE M., Chief Electrical Engineer, State of California Department of Engineering, Sacramento, Cal.
TAYLOR, EDWARD, Designing Engineer, General Electric Co., Chicago, Ill.
VOLKMANN, WILLIAM, Jr., Assistant to Chief Engineer, Toronto Power Co., Toronto & Niagara Power Co., Toronto Railway Co., Toronto, Ont.
WARNER, WILLIAM H., Distribution Engineer, New York & Queens Electric Light & Power Co., Long Island City, N. Y.
YAMBERT, D. W., Electrical Engineer, France Stone Co., Toledo, O.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 31, 1920.

Aabye, Jorgen, New York, N. Y.
Abbett, Hugh W., Indianapolis, Ind.
Adams, Frederic, O., Toronto, Ont.
Anderson, Arthur H., Watervliet, N. Y.
Andrews, Alvin G., Detroit, Mich.
Armstrong, H. V., Toronto, Ont.
Armstrong, Morris S., Philadelphia, Pa.
Bagnall, George E., Detroit, Mich.
Balhatchet, Harold S., Toronto, Ont.
Baker, Clark E., Schenectady, N. Y.
Beach, Earl L., Detroit, Mich.
Beck, Chas. J., Philadelphia, Pa.
Benson, Henry W., Lynn, Mass.
Beymer, Oliver H., Pittsfield, Mass.
Bisbee, Frederick C., Philadelphia, Pa.
Boruch, Edwin R., Schenectady, N. Y.
Carraway, Thomas W., Camp Normoyle, Texas.
Cook, Querin H., Chicago, Ill.
Copp, Frank T., (Member), New Orleans, La.
Cox, Harold N., Toronto, Ont.
Cross, Samuel A., Van Nest, N. Y.
Culligan, Michael, Toronto, Ont.
Dane, Francis W., Boston, Mass.
Danner, Roy, Detroit, Mich.
de Castillo, S. R., New York, N. Y.
De Vitis, Rene M. S., (Member), Chicago, Ill.
Dolen, David O., Libby, Mont.
Droege, Harry G., Detroit, Mich.
Elwell, John M., Philadelphia, Pa.
Fairlie, Howard W., Montreal, Que.
Farmer, Kenneth V., (Member), Syracuse, N. Y.
Feder, Tobias, M., Kenova, W. Va.
Frey, George F., New York, N. Y.
Furr, Guy L., Bluefield, W. Va.
Galbraith, A. R., Toronto, Ont.
Gifford, Frederic A., W. Lynn, Mass.
Gladwell, Reginald R., Schenectady, N. Y.
Goodole, John C., Ann Arbor, Mich.
Goodwin, Harold L., Cambridge, Mass.
Gould, William T., Boston, Mass.
Grau, William F., Cincinnati, Ohio.
Hackbusch, Ralph A., Toronto, Ont.
Hannon, John W., South Bend, Ind.
Hansel, Floyd M., Ft. Wayne, Ind.
Harrison, S. Henry, Boston, Mass.
Hayball, Walter, Detroit, Mich.
Hefner, Geo. R., Brooklyn, N. Y.
Hodtum, Joseph B., Cincinnati, Ohio.
Hudson, Walter F., Utica, N. Y.
Jett, Charles H., (Fellow), Denver, Colo.
Jordan, Lee J., Toronto, Ont.
Kane, Thomas L., Jr., E. Pittsburgh, Pa.
Kent, James H., Kansas City, Mo.
Kipp, Louis H., Phoenix, Ariz.
Knight, Frank M., Philadelphia, Pa.
Koch, Carl J., Milwaukee, Wis.
Larson, Herman R., E. Pittsburgh, Pa.
Leath, Oliver M., E. Pittsburgh, Pa.
Leet, Arthur W., Detroit, Mich.
Lockrow, Laurice L., Houston, Texas.
Lundstrom, Axel W., Maspeth, L. I.
Lynch, John T., St. Louis, Mo.
MacAlister, James E., (Member), Detroit, Mich.
Maiers, Matthias J., Milwaukee, Wis.
Maloney, Philip R., Chicago, Ill.
Martin, William R., New London, Conn.
Minshull, George R., Detroit, Mich.
Moore, Harry L., Milwaukee, Wis.
Morash, J. R., Chicago, Ill.
Morrill, Leroy B., W. Lynn, Mass.
Muehlberger, George C., Highlandtown, Mass.
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McLean, Allan, Brooklyn, N. Y.
McQuown, William K., (Member), Washington, D. C.
Nealis, F. H., Cincinnati, Ohio.
Noble, Egerton S., Timmins, Ont.
Norman, Frederick E., New York, N. Y.
O'Banion, Albert L., Bridgeport, Conn.
Obata, Mankichiro, Brookline, Mass.
Owen, Casper J., New York, N. Y.
Parisian, Gurden R., Detroit, Mich.
Parks, Robert C., Boston, Mass.
Patch, James W., (Member), Ft. Wayne, Ind.
Pennock, Frederick W., (Member), Montreal, Que.
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Wheeler, Stanley M., E. Pittsburgh, Pa.
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Wilder, Willard S., Milwaukee, Wis.
Wilson, William S., Toronto, Ont.
Witt, Leroy C., Grace, Idaho.
Young, Benj. U., Boulder, Colo
Young, Hadley E., Mansfield, Ohio
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McLanahan, All, (Member), Limonar, Cuba
Miles, Richard A., London, Eng.
Rowe, H. Gordon, Rugby, Eng.
Sample, Mat, Chuquicamata, Chile, S. A.
Total 17.

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11706 Buchanan, David L., Drexel Institute
11707 Maurer, Keith L., Sheffield Scientific School
11708 Olson, Walter D., Oregon Agricultural College
11709 Bailey, Alden L., New York Electrical School
11710 Weaver, Elmer B., Purdue University
11711 Lorber, Abram, Purdue University
11712 Ballenger, Ralph A., Purdue University
11713 Miller, Glen L., Purdue University
11714 McCarter, Walter, Purdue University
11715 Routson, Luther B., Purdue University
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11720 Diggs, Dudley P., Purdue University
11721 Schultz, Marion I., Purdue University
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11738 Epstein, Monroe E., University of Missouri
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11828 Elliott, John L., Oregon State Agricultural College
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11863 Fisken, James B., State College of Washington
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11875 Weil, Leon, Central Technical School
11876 Phillips, Samuel, Central Technical School
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11883 Hepburn, Dugald, University of Toronto
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11998 Stultz, Raymond, Purdue University
11999 Krom; Myron E., Purdue Universityx
12000 Rives, Harold D., Purdue University
12001 Hagenbuck, Raymond O., Purdue University
12002 Briggs, Harold L., Purdue University
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12043 Wing, Henry R., Armour Institute of Technology
12044 Pearce, William W., Armour Institute of Technology
12045 Hesson, William G., Armour Institute of Technology
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12048 Kihlstrom, Harry C., Armour Institute of Technology
12049 Schreiber, Herbert F., Armour Institute of Technology
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12051 Wingard, Glenn A., Leland Stanford Jr., University
12052 Blakeslee, Edwin M., Leland Stanford Jr., University
12053 Overacker, Horace E., Leland Stanford Jr., University
12054 Dinapoli, Domenick, Leland Stanford Jr., University
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12056 Kallam, Floyd, Leland Stanford Jr., University
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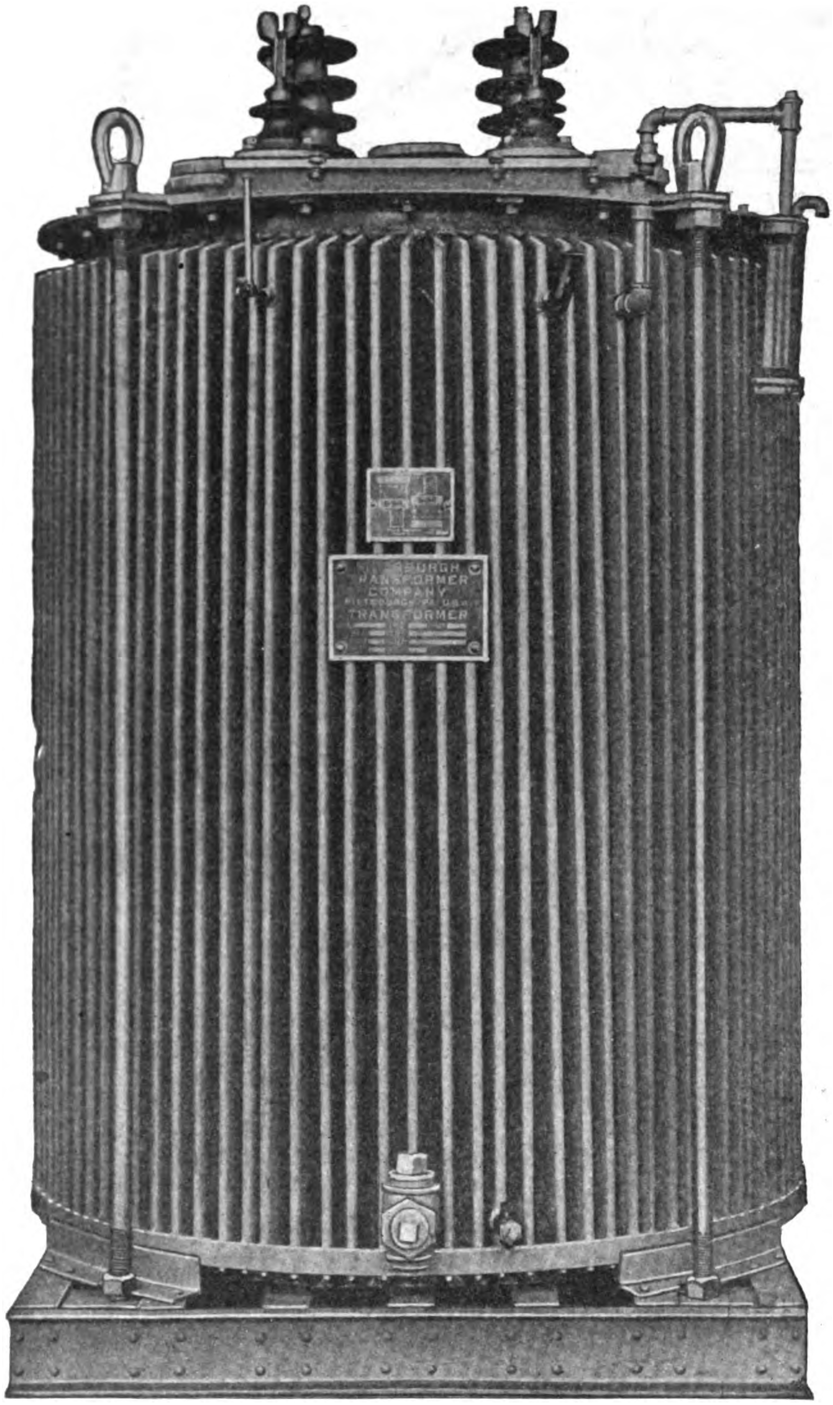

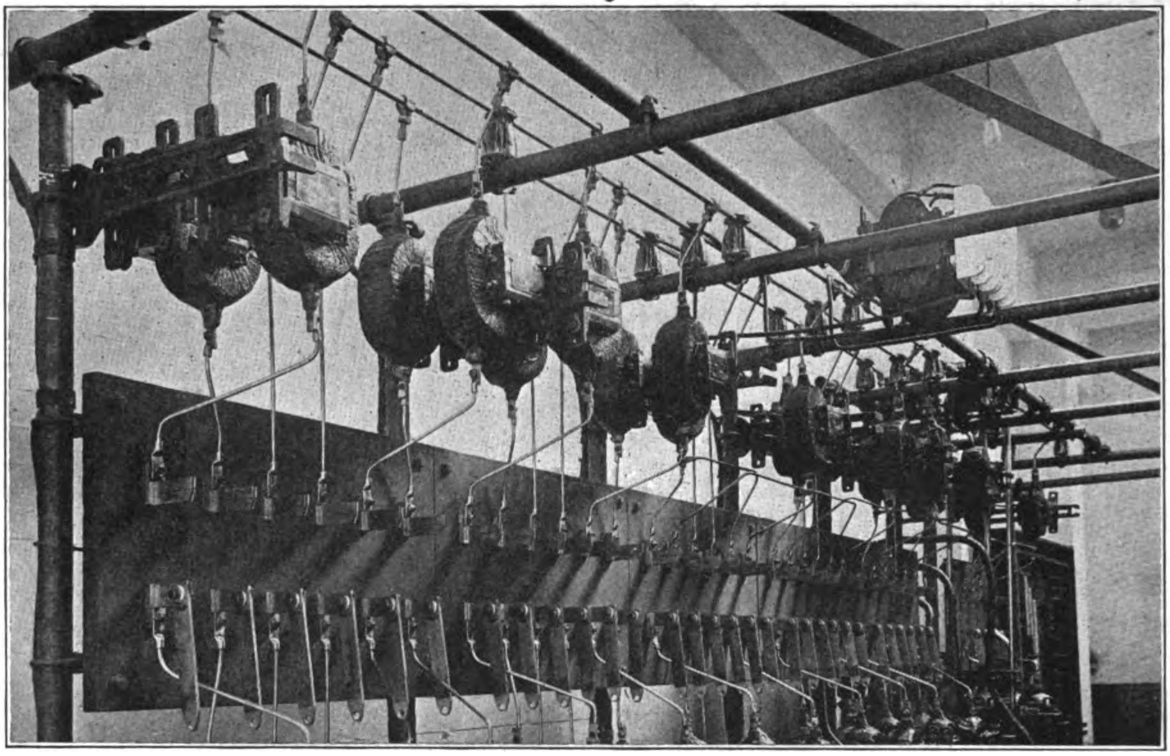

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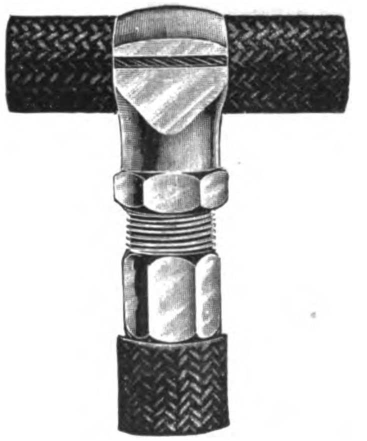

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A new edition of our **Electrical Conductor Handbook** was published last month. If your name is not already on our mailing list, fill out and mail us the coupon.

ALUMINUM COMPANY OF AMERICA

PITTSBURGH, U. S. A.

J. A. I. E. E.

Aluminum Company of America
2400 Oliver Bldg., Pittsburgh, Pa.
Please send Handbook to the undersigned without charge or obligation.

Name ....

Address ....

....

....

Fuse hunting

—while production waits

WHENEVER a fuse blows, production is stopped.

Then, while a workman hunts up an electrician and the electrician tests for the blown fuse, the motor, the motor-driven machinery, and a little knot of workmen go on a short vacation.

Fuse hunting takes more time than most people realize. Time it yourself in your own plant. You will find that the average time required to locate and replace a blown fuse is twelve minutes.

With the Condit Type N 1 Oil Motor Starter, fuse hunting is never necessary. This switch does not protect by fuses. In the event of overload, short-circuit, undervoltage or single phase running, the ball-bearing latch is tripped automatically and the contacts are opened under oil.

A Condit representative (located near you) will be glad to call to tell you more about the advantages of a circuit breaker.

CONDIT

Condit Type N-1 Oil Motor Starter 30 Amperes 600 Volts.

CONDIT ELECTRICAL MANUFACTURING CO.

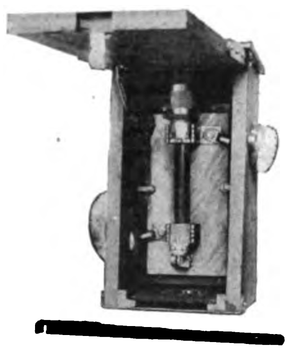
Manufacturers of Electrical Protective Devices

South Boston, No. 27, Mass.

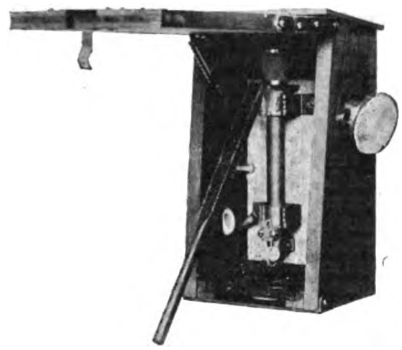
MATTHEWS SAFETY STICK
and the
NEW TYPE CG MATTHEWS FUSWITCH

A Matthews Safety Stick is packed in every other Type CG Matthews Fuswitch

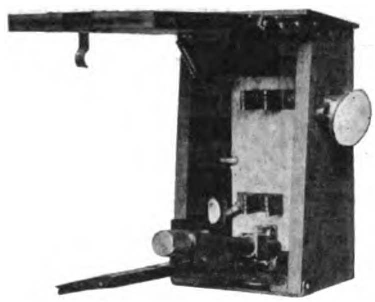
It is used first to open the door of the Type CG Matthews Fuswitch



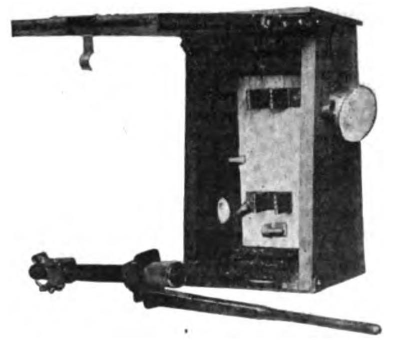
The Matthews Safety Stick makes it entirely unnecessary for a workman to touch the box



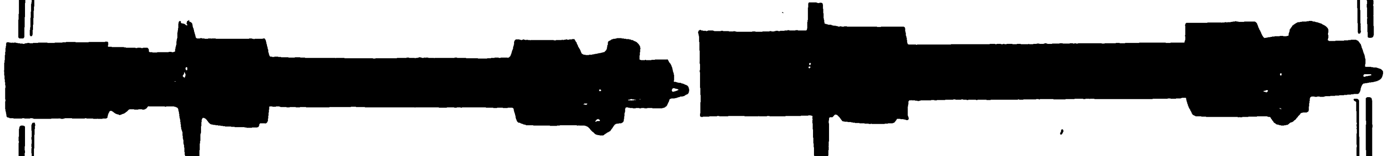
After the door is open the Matthews Safety Stick is used to pull down or disconnect the fuse cartridge of a Type CG Matthews Fuswitch



When the fuse cartridge has been pulled down to a right angle it can be easily removed by moving the Matthews Safety Stick to the right



When the cartridge is entirely removed from the Type CG Matthews Fuswitch it can then be taken off Matthews Safety Stick



"Close up" of the Fuswitch which is both a fuse and a switch. Note the large mass of metal at the explosion end. This radiates the heat and prevents the carbonization of the insulated tube

W. N. MATTHEWS, PRESIDENT AND TREASURER

MARTIN J. WOLF, VICE-PRESIDENT

CLAUDE L. MATTHEWS, VICE-PRESIDENT AND SECRETARY

W. N. MATTHEWS & BROTHER

INCORPORATED

MANUFACTURERS OF MATTHEWS PATENTED SPECIALTIES

ST. LOUIS, U. S. A.

Aside from 100 other uses there are thousands of places where *C-H Electric Space Heaters* may be used—some proven uses are indicated

Heating Office and Charging Batteries

"We have a 500 Volt D. C. line into our place of business and several of the employes have cars which have storage batteries that need charging from time to time. Well, we got together and talked about harnessing the 500 Volt circuit. We had some C-H Space Heaters so here is what we did:—By using five heaters we obtained five amperes. Added five more heaters hooked in multiple which gave us a little less than ten amperes.

We found that by using the Space Heaters in this way we could kill two birds with one stone, i. e., heat the office and at the same time charge our batteries."

Electric Locomotives

"We are using C-H Space Heaters to prevent moisture from getting in the motors and electrical wiring of our electric locomotives by placing six or more heaters on a rack under the locomotives. The power is applied when the locomotives are at rest in wet places in the tunnels."

Oil Switches

"The oil switch inspector of a New England Power Co., had considerable trouble with condensation of moisture in our switches of the 110,000 volt type, until a C-H Heater was used to keep the temperature uniform."

Drying Out Transformer Cores and Motors

"An asbestos lined box made of sheet steel in which we will place about thirty Space Heaters properly connected to switches so as to be able to get different heats, and so designed that when used with a small blower all the air passing through the box will pass over all the space heater surfaces. We anticipate using this air heater and blower for drying out transformer cores on the floor under canvas, large motors; and in fact, anywhere where a steady current of hot air (about 90 degrees Cent.) is necessary."

High Tension Lighting Arresters

"We have built houses over our 80,000 volt lightning arresters to protect them from freezing and were somewhat puzzled as how to heat the buildings until we thought of your Space Heaters. So we placed three in each house and these keep the solution from freezing and keep the arresters in operative condition."

Protection of Underground Motor and Generator Against Precipitation of Moisture

"In several of our underground pumping stations the atmosphere is close to the dew point at all times. As the normal underground temperature is approximately 55 degrees Fahr., any slight change in ventilation in the winter frequently causes a considerable precipitation of moisture on everything in the pump station. In our two dampest pump stations we are using C-H Electric Space Heaters under the motor, there being a space of approximately three-quarters of an inch in height from the under surface of the motor frame to the top of the bed plate. This heater is in service at all times, and, when the motor is not running, it is covered with a box made of No. 22 gauge galvanized iron.

We are using a similar arrangement on some of our large underground motors. The C-H Space Heater is the only one we have with cross section small enough to go into the limited space under our centrifugal pump motors."

In Electrical Laboratory Work

"In electrical engineering it is often necessary to determine temperature coefficient and heating effects on certain apparatus. With four C-H Heaters fairly distributed degrees of heat are obtainable. Thus substantial apparatus is obtained for this purpose at a minimum of expense. Since they are compact and stand rough handling they lend themselves well for laboratory work."

Transformer Rooms, Repair Shop, Lavatories

"We use four Heaters in series on 440 volts, to heat our transformer rooms, repair shop, and lavatories. They make good heaters at a reasonable price."

Substation Heating

"The United Illuminating Co., for whom I work, uses Space Heaters to make work in their substations comfortable."

Power House and Office Heating

"For your information, we use quite a number of these Space Heaters for heating our power house, as well as our office uptown."

At the Gatun Hydro-Electric Station, Panama Canal

"Space Heaters are used at the Gatun Hydro-Electric Station, Panama Canal, in the generators whenever they are shut down, to maintain a temperature sufficient to prevent the insulation from absorbing moisture from the surrounding air. They are permanently mounted on the distance ring of the unit just under the armature winding, 10-500 watt units are used. The use of these heaters as above mentioned has proved very satisfactory."

Time Clock

"One of these Space Heaters has proven its merits in a Cincinnati Time Recording Clock which was exposed to cold and damp weather."

Drying Telephone Switchboards, And Load Testing

"I have used C-H Heaters successfully for drying out telephone switchboards. I find them very convenient also for providing artificial testing loads in blocks of 5 amperes."

Armature Test Work

"I have a good and wide range of use for your Space Heaters, in an armature test arrangement connected to a rheostat face. This also gives the best range of current for general tests that I have found yet."

Resistor Capacity For Armature Testing

"While in charge of a Motor Department, we had a large armature to rewind and trying to test it out found that our lamp banks did not have current capacity enough to give our Mils ammeter sufficient throw on the scales. So we rigged up six C-H Heaters in connection with one lamp bank and it did the trick O. K."

Temporary Resistor

"At Sea Breeze, N. Y., while with a Construction Co., we had to wire for an air compressor connected with water system and when the outfit came it had a 110 volt single phase 1 H. P. motor and we had wired for a 220 volt motor as our instruction called for. As they wanted to use the water system at once we used two of your Heaters as temporary resistance and the motor ran for about five weeks in this manner until a 220 volt motor was sent out from the manufacturer at which time we changed the motors and took out the heaters. It ran satisfactorily in every respect and the heaters were mounted direct to the wall with screws and on porcelain insulators with asbestos under them."

Emergency Resistors

"I have at various times had occasion to use C-H Space Heaters to my entire satisfaction I have used them both singly and in parallel for getting any desired value of current. Occasion often arises to use them in repairing broken down resistances and also for controlling the speed of motors. Their compact construction makes it possible to install them in emergency cases and also on permanent jobs and they have proven to be a great help to me."

Miscellaneous Applications in and About Electric Water Power Plants

"We have found C-H Electric Heaters very useful installed in the cast iron tubes which house the floats operating our Head and Tail Race Gauges. Due to the severe climate here these floats would be frozen fast at times if it were not for electric heaters installed along the sides of the casing, which keeps the temperature above freezing point." * * * *

"C-H Electric Space Heaters placed in front of headgates keep the ice from forming, thus allowing the gates to be raised or lowered at any time during the winter."

* * * *

"Space Heaters replace carbon lamps which we have been using in the past to keep the headgates at the intake of our electric power development at Chasm Falls, N. Y. from freezing up and the success we have had with the lamps has suggested the use of your Space Heaters for the same purpose." * * * *

"We also will place one or two of these heaters in the opening at the top of the air-vent leading to our penstock to keep ice from forming, so that there will be no danger of the pipe collapsing in case of an obstruction to the water at the racks."

* * * *

"We have eleven air relief valve houses along our two and a half miles of penstock in which we use C-H Space Heaters to keep the valves from freezing."

Attached to Washing Machines

"Attaching a C-H Electric Space Heater to my Laundryette electric washing machine keeps the water hot." * * * *

The new Booklet "Dictionary of Uses" C-H Electric Space Heaters" should be in your files.

The Cutler-Hammer Mfg. Co.

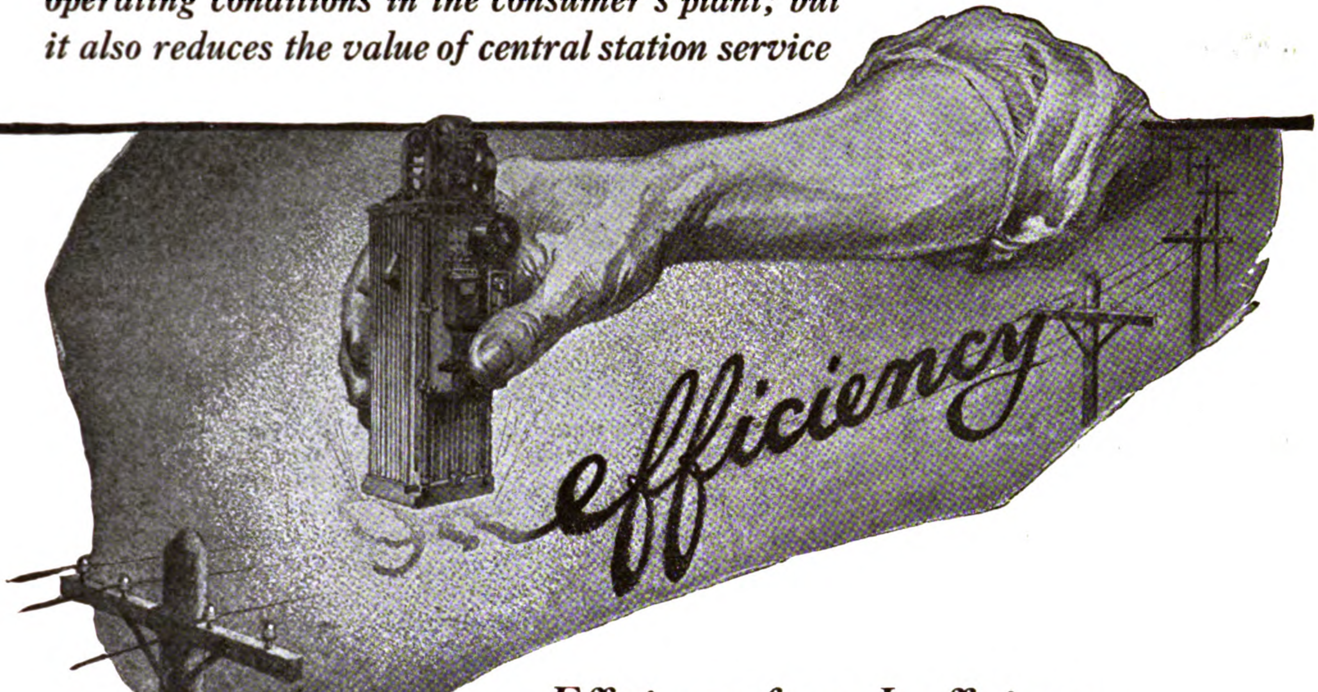
Works:
MILWAUKEE and NEW YORK

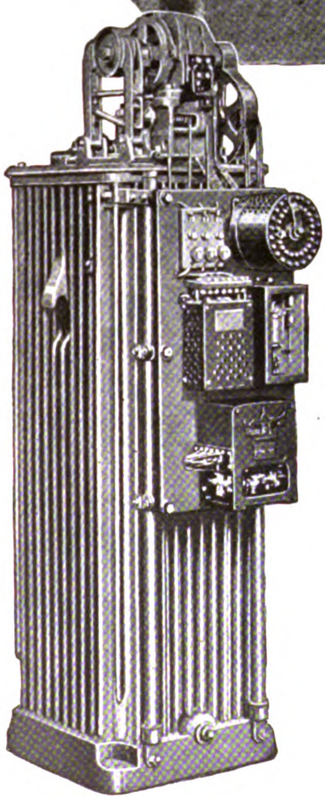
Offices:
New York, Chicago, Boston, Philadelphia, Pittsburg, Cleveland, Cincinnati, Detroit, San Francisco, Los Angeles, Seattle, Birmingham.

"Two Feet of Electrical Heat"

If your Electrical Supply Jobber has no stock write to the Cutler-Hammer District Office nearest you for prompt attention.

Inefficient distribution because of poor voltage regulation not only affects operating conditions in the consumer's plant; but it also reduces the value of central station service





Efficiency from Inefficiency through G-E Induction Voltage Regulators

OF course, you know the size of your feeders and the size and location of transformers, but how much do you know about the voltage at the ends of your feeders, especially at times of peak load?

There is a G-E Induction Voltage Regulator for every class of service.

Call in our engineering specialist and let him show you how the added earning power of a regulator will soon pay for itself.

His services are yours for the asking.

General Electric Company

General Office Schenectady, N.Y.

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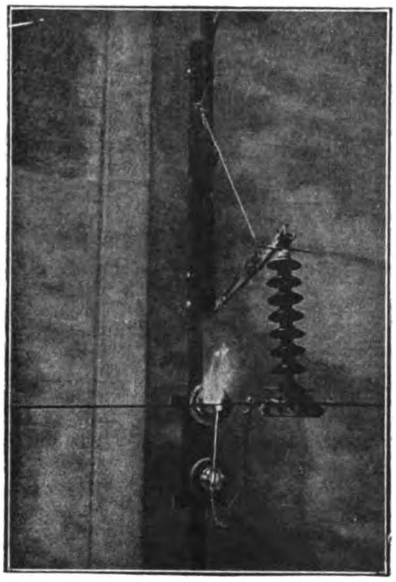
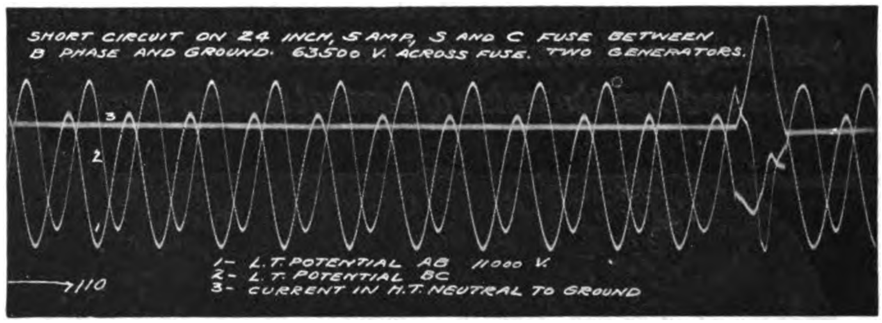
33B-13

S&C HIGH POTENTIAL FUSES



S&C Fuse clearing 66,000 volt short circuit with two 9000Kw. generators in parallel.



Oscillogram record of test. The circuit was cleared in one-half cycle or 0.02 seconds. The 66,000 volt S&C Fuse was connected between one phase and neutral on a 110,000 volt circuit of a very large hydro electric station.

REMARKABLY EFFECTIVE

The accompanying illustration of a fuse blowing under unusually severe conditions clearly demonstrates the ease of operation, freedom from severe arcing, or other evidence of distress.

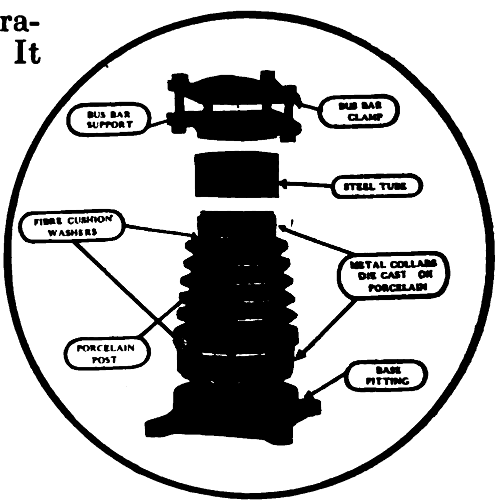
The oscillogram record of this test further emphasizes this remarkable performance. Write for further information concerning the application of S & C Fuses for protective purposes.

SCHWEITZER & CONRAD INC

4435 RAVENSWOOD AVENUE CHICAGO, ILLINOIS U.S.A.

REMEMBER "FRANKLIN" BY THESE THINGS—

EVERY device in the "FRANKLIN" line of generating station equipment is a safer thing to use. It has been designed for that definite purpose, and it is safer—for instance—



The "Franklin" Post Type Insulator is safer because the metal bushings are die cast directly on to the porcelain, then machined and threaded to receive the fittings. There is no cement to crumble, no clamps to cause spot pressure, no dirt pockets. It gives great strength and durability. ***It's safer.***

The "Franklin" Pothead is safer because two clamping members automatically bell out the lead sheath of the cable and eliminate all possible concentration of static strain. It makes a waterproof, solderless joint. It is very strong and very simple to install. ***It's safer.***

The "Franklin" Disconnecting Switch is safer because it combines the safer qualities of the "Franklin" Insulator with the "Franklin" Positive Lock. This lock makes a closed bridge across the blade at such an angle that resultant electric forces tend to hold it more tightly closed. Yet one pull of the hooksticks opens both lock and blade. It is very strong and sure. ***It's safer.***

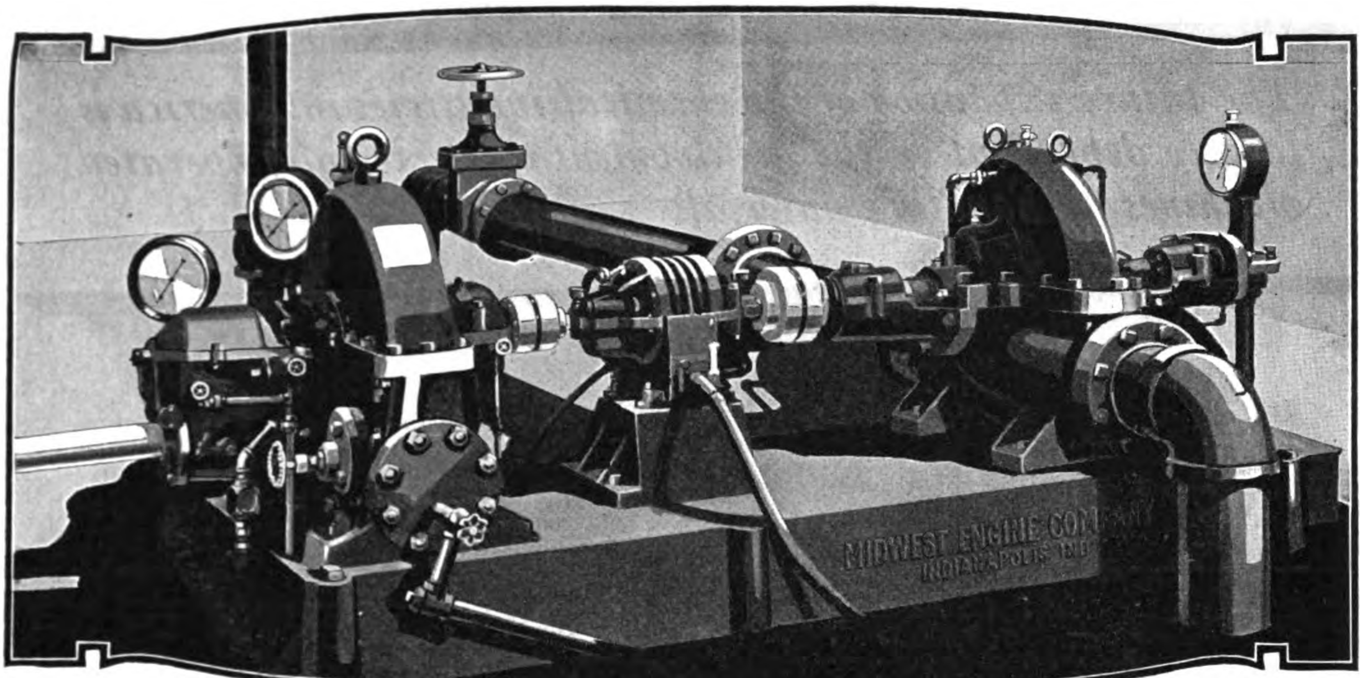
These are just three features of the "FRANKLIN" line. Test them. Try them. Study them. Use them. See why it is we say—*"Install the 'FRANKLIN' and forget it."* Every "FRANKLIN" device has distinct refinements that make it better, surer and safer. Write for our bulletins.

ELECTRICAL DEVELOPMENT & MACHINE COMPANY

Eastern Sales Agent **Philadelphia**

UTILITY PRODUCTS CORPORATION

50 Church Street · New York City



MIDWEST TURBINES

High Duty Pumping Plants Require Midwest Turbines

High priced coal makes every pound of steam that can be saved a net profit against your operating cost. Where you need exhaust steam for feed water heaters, Midwest Engineers can design a turbine which will use the required amount of steam and save the surplus coal used where conditions are not balanced.

Where steam heat is needed you can use your Midwest Turbines as reducing valves to your heating system, thereby getting your heat at a minimum cost.

Midwest Turbines and Pumps have the combined qualities of extreme simplicity and highest economy.

Complete information on request.

Midwest Engine Co., Indianapolis, U. S. A.

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El Paso
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Pittsburg
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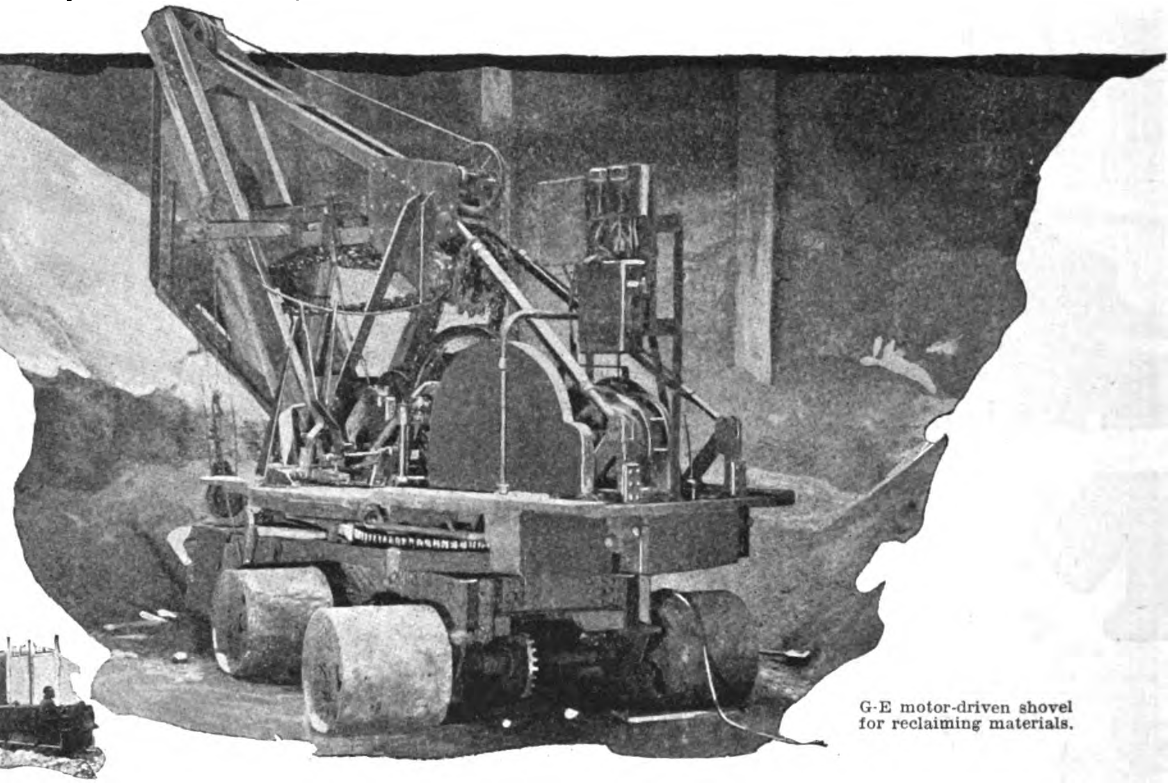
St. Louis
St. Paul
Seattle
Tulsa

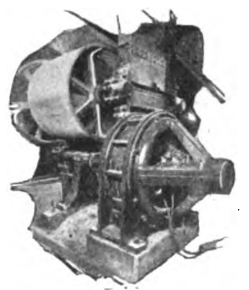
DEPENDABLE POWER

The future expansion of the chemical industries in America is largely dependent on the development of electrically operated machines for handling materials

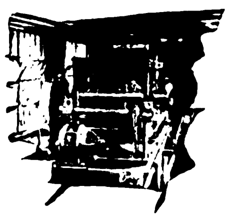


G-E motor-driven shovel for reclaiming materials.

G-E storage battery locomotive hauling salt cake.



G-E induction motor driving reclaiming conveyor.



G-E motor-driven mixing car in large glass works.

Specify Machines G-E Built or Equipped

Yesterday a few tons to be moved—today mountainous heaps. This is the new problem of material handling which the expanding chemical industry is solving *with electricity.* No other solution is so satisfactory.

Many plants, highly efficient in their strictly chemical functions, are achieving great economies by handling material with electrical equipment—good for 24 hours a day in spite of dust, fumes, temperature extremes and severe mechanical strains. The reliability of this modern electrical machinery is based on utmost skill in design and long manufacturing experience. G-E products have this substantial basis.

General Electric equipped machinery is giving satisfactory service in a wide variety of installations. G-E engineers are ready to co-operate with builders of material handling machinery and to help solve new problems this machinery must meet.

The G-E specialist in our nearest office is ready to work with you—ask him to call

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities

43B-535

℞ For Motors and Generators not up to par—

MORGANITE BRUSHES

OFTENTIMES motor troubles are due to inferior and unsuitable brushes. One sure way to eliminate such trouble is to equip motors with the right grade of *Morganite Brushes.*

The time and thought put into the selection of the most suitable grade of brush for any given set of conditions are amply justified by the results obtained.

Morganite

brushes are made in an infinite variety of shapes and sizes and in the following distinctive classes:

Standard Morganite Brushes
Hard Morganite Brushes
Copper Morganite Brushes
Morganite Carbon Brushes
Morganite Electro-Graphitic Brushes

Our research laboratories have rendered the most valuable help to the electrical profession. We will be glad to know *your* brush requirements and to recommend the proper *Morganite Brush* for any general or specific use.

MORGANITE BRUSH CO., Inc.

Main Office and Factory: 519 West 38th St., New York

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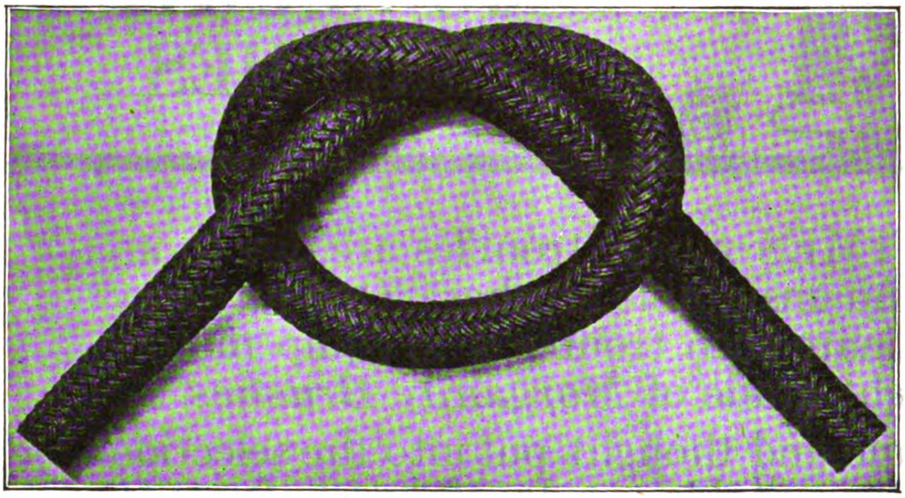
Simplex Hard Service Cable

FOR PORTABLE TOOLS AND LIGHTS



Flexible as a lamp cord. Protected by a seine twine braid specially treated to withstand rough use. Recommended for portable tools and lights in machine shops, garages, shipyards and on any engineering or construction work where conditions are severe and continuous service is essential.

Send for descriptive circular No. 2.

SIMPLEX WIRE & CABLE CO

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We make with strict attention to quality of material and workmanship:

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Telephone Wire
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Insulated Wires and
Cables of all kinds.

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Transformers

If you are in search of a special transformer to meet your particular needs, it will pay you to investigate the Packard.

No matter what type or size you require, we can meet your specification. Packard transformers stand for long, unbroken service and high efficiency. **26** years' factory experience make them so.

Write for Bulletin.

The Packard Electric Company

Warren, Ohio

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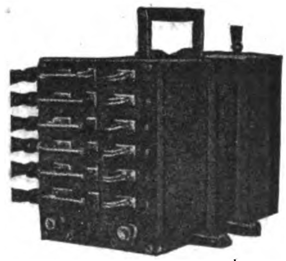
Industrial Transformers

Water Cooled Furnace Transformer.

With the tremendous increase in industrial activity there arise many process-development problems requiring special transformers for laboratory and experimental work.

The American Transformer Co. is not only well prepared to fill your special requirements with respect to laboratory transformers, but offers to study your transformer problems throughout the development of a process to the commercial stage.



Portable ½-kva. Laboratory Transformer 1 to 64 Volts in 1 Volt Steps

The American Transformer Company

176 Emmet Street, Newark, N. J.

POWER FACTOR
AND
COST OF SERVICE

The rapidly increasing tendency toward such refinements in power contracts as will reflect accurately the various elements entering into cost of service demands a simple and unfailing means of measuring power factor.

Our *Phasing Transformers* and standard meter equipment meet all requirements.

THE STATES COMPANY

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TYPE 102

DECADE RESISTANCE BOXES

A practical resistance unit for laboratory use. The units are wound by the Ayrton-Perry method thus having a minimum of inductance and distributed capacitance. Adapted for use with direct or alternating current of any frequency, including radio.

Each dial has eleven points, thus making it a complete unit. The multiple contact brushes insure low and constant resistance. No plugs to work loose or become lost.

Made in seven sizes from two to four dials with total resistances of from 11 to 11,110 ohms.

Bulletin 201 E will be sent on request.

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IF IT'S **PARANITE** IT'S RIGHT

Rubber Covered Wires and Cables
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Lampcords (Silk and Cotton)
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For 30 Years the Standard

Indiana Rubber and Insulated Wire Co.

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Electrical Testing Laboratories

Inspections—Tests—Research

Tests may be used by the purchaser for the following purposes:

(1) To determine the quality of competing samples.
This enables the purchase of the best quality for the money.

(2) To make sure that shipments comply with specifications.
This makes possible the assurance to the customer that shipments match buying samples.

(3) To furnish an impartial decision in case of disputes between purchaser and manufacturer.

Testing places the whole buying problem on a sound basis.

ADDRESS:

80th Street and East End Ave.
New York, N. Y.

I-T-E

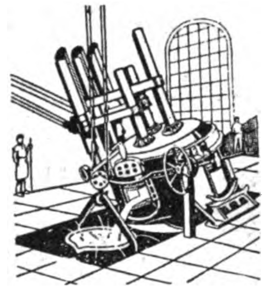
CIRCUIT BREAKERS

WE know of one manufacturing concern in this country that has been spending Seven Thousand Dollars a month on fuses.

I-T-E CIRCUIT BREAKERS are going to reduce this monthly bill.

The Cutter Company
Philadelphia

Moore Rapid "Lectromelt" Steel Furnaces



Design by engineers fortified with years of experience in both the central station and furnace business. Moore furnaces turn out more steel, produce better load factors, insure more evenly balanced loads, and maintain best power factor conditions. They create profitable power loads and make for satisfied power customers.

Pittsburgh Electric Furnace Corporation

"Makers of Furnaces for Steel, Iron, Brass and Carbide" **Pittsburgh, U. S. A.**

TRANSFORMER SPECIALISTS

We are pleased to quote prices and delivery on transformers singly or in quantity.

ACME APPARATUS CO.

31 Windsor St. Cambridge, 39, Mass.

Transformer Engineers and Manufacturers

It's the labor that counts—

JOHNS-MANVILLE Fibre Conduit weighs one-fifth as much as tile duct. It is laid more quickly.

Trenches can follow grade changes and always be of minimum depth.

Pulling cables is a quick job owing to the smooth bore.

Yet, in addition, Johns-Manville Fibre Conduit actually costs less to buy than tile duct.

Can there be more convincing arguments than these for the use of a material that has the unequalled durability and protection value of Fibre Conduit?

JOHNS-MANVILLE
Incorporated
Madison Ave. and 41st St., New York City
10 Factories—Branches in 64 Large Cities
For Canada:
CANADIAN-JOHNS-MANVILLE CO., Ltd.,
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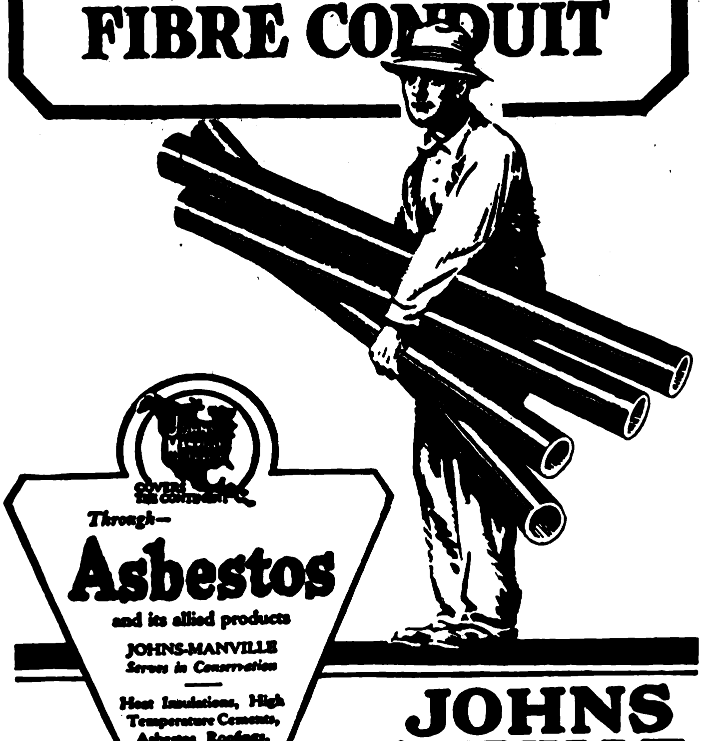
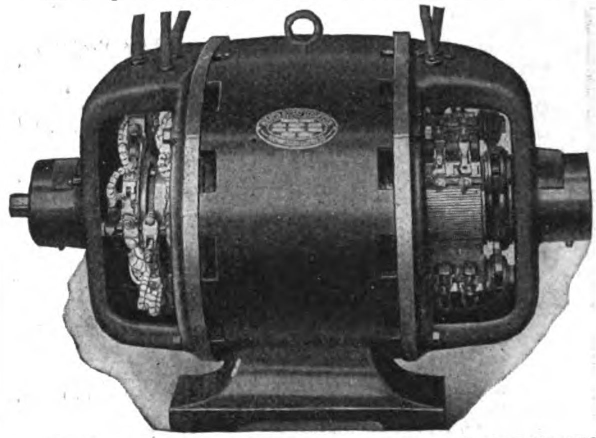
JOHNS-MANVILLE FIBRE CONDUIT



JOHNS MANVILLE ELECTRICAL MATERIALS

THE NEW "MARTIN" A.C. TO D.C.

Rotary Converter and Synchronous Motor



This machine is designed to operate on 110, 220, 440 Volts; 25, 30, and 60 cycles A. C. Delivers D. C. of any desired voltage up to 250. Made in capacities from 100 Watts up to 100 Kw.

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Also Mfrs. of "AK" Variable Speed A. C. Motors.
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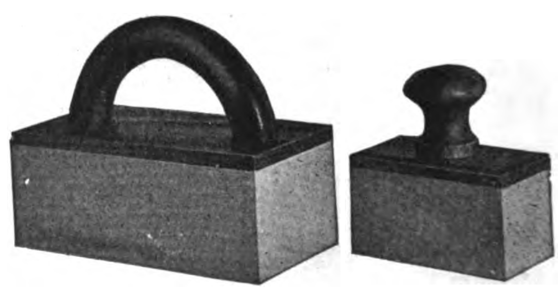

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A. I. E. E. MEMBERSHIP BADGES

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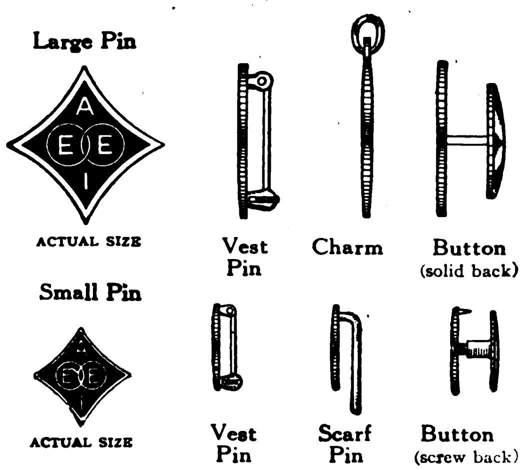

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Size	Style Back	Price	Style No.
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Large	Charm	4.50	2
Large	Lapel Button (Solid Back)	6.00	3
Small	Vest Pin	3.00	4
Small	Scarf Pin	3.50	5
Small	Lapel Button (Plated Screw Back)	3.00	6

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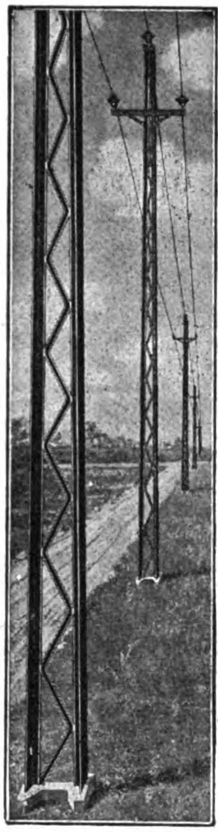
Bates Steel Pole Treatise



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Classified Advertiser's Index for Buyers

A classified and comprehensive list of manufacturers and agents for machinery and supplies used in the electrical and allied industries; professional consultants and laboratories.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 46.

(Continued on page 44.)

Classified Advertiser's Index for Buyers—*Continued.*

(Continued from page 42.)

CLASSIFIED
ADVERTISEMENTS

RATES: Forty cents per line; minimum charge based on use of five lines; maximum space cannot exceed twenty lines.

Copy should be received by the 15th of the month for insertion in the following issue.

FOR SALE: A complete set of the A. I. E. E. TRANSACTIONS, bound in cloth, from Vol. I (1884) to Vol. XXXVII (1918) inclusive. Boxed, ready for shipment; price on request. Address Class-102, A. I. E. E. JOURNAL.

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CLASSIFIED ADVERTISEMENTS

Established principally for the convenience of JOURNAL readers, Classified Advertisements are now accepted for publication in this Section.

Items regarding the sale or purchase of used equipment are particularly favored, but it is not limited to such announcements; others of interest to readers and which do not properly belong in the general advertising pages may also be inserted.

The JOURNAL of the AMERICAN INSTITUTE of ELECTRICAL ENGINEERS

33 West 39th St., New York

ALPHABETICAL LIST OF ADVERTISERS

(For classified list of Advertisers see Pages 42 & 44)


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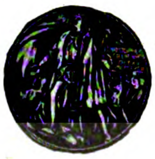

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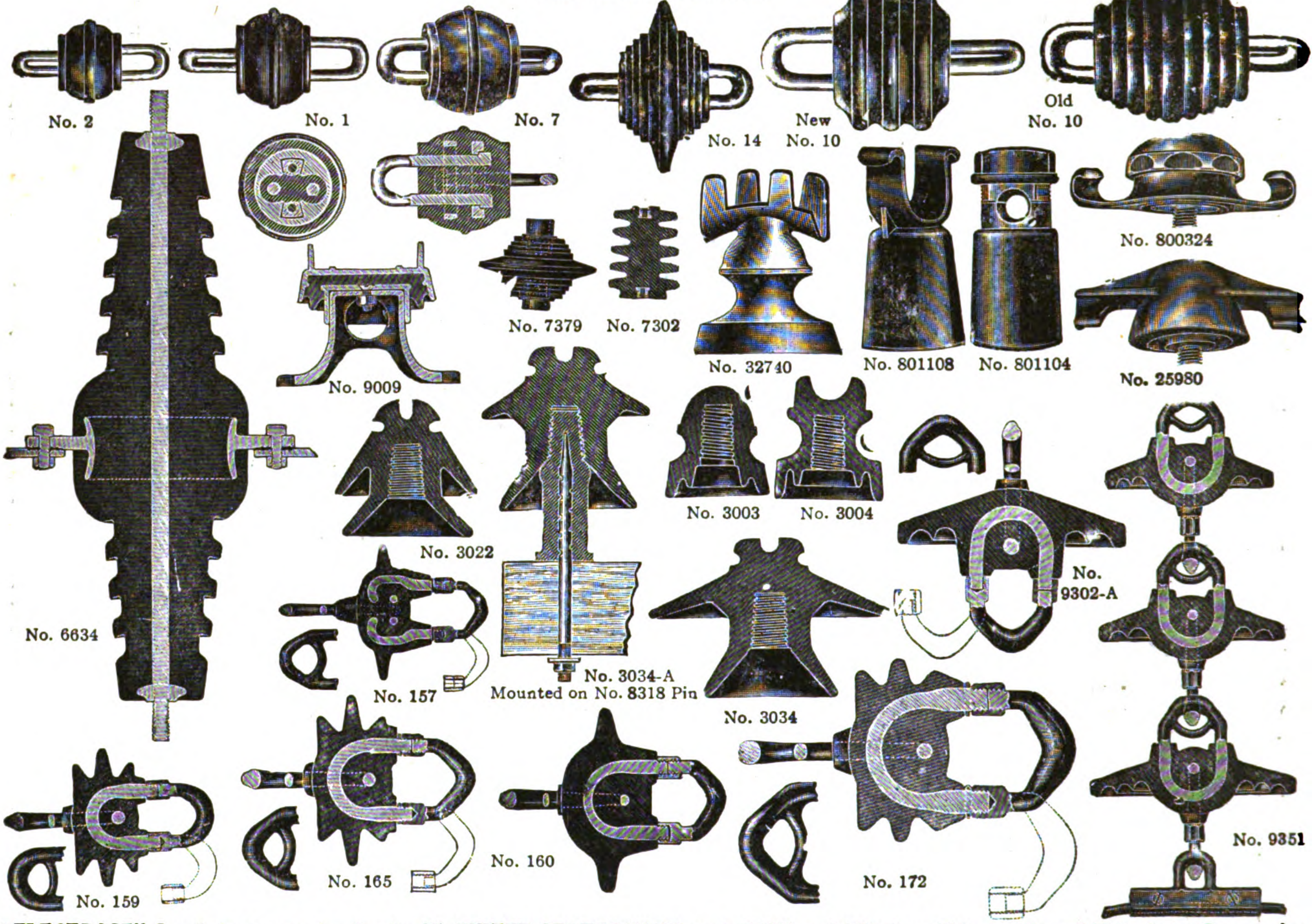

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